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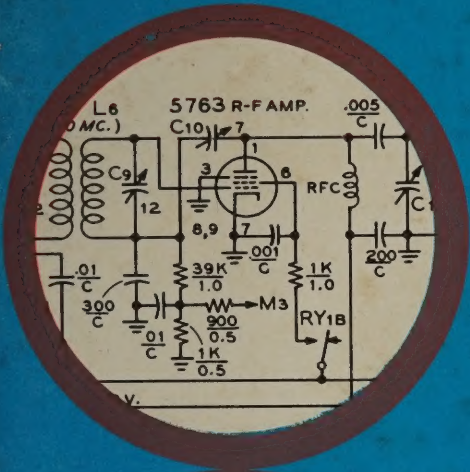

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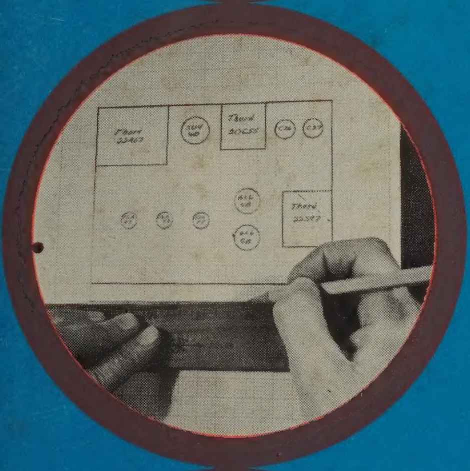

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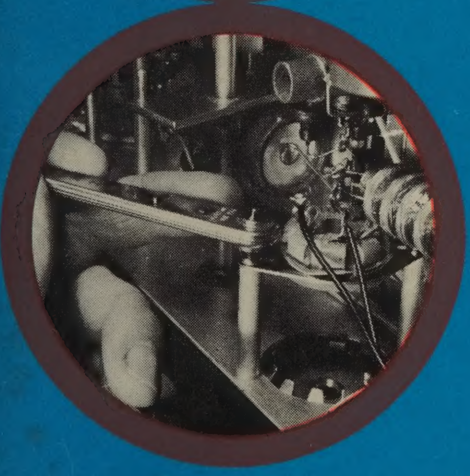

PRACTICES

by Robert Lewis W8MQU

radioamateurs! hi-fi enthusiasts! kit builders!

YOUR GUIDE TO BETTER EQUIPMENT!

ELECTRONIC CONSTRUCTION HANDBOOK

by Robert F. Lewis, W8MQU

Radio Publications, Inc.
Wilton, Conn.

ELECTRONIC CONSTRUCTION HANDBOOK

By Robert F. Lewis, W8MQU

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ELECTRONIC CONSTRUCTION HANDBOOK

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FOREWORD

During the past six decades vast changes have occurred in scientific fields which were born around the turn of the century. In particular, the field of electronics has made unbelievable advances. In sixty short years radio and electronics have advanced from the crude coherer detector and spark-gap transmitter to the elaborate multi-tube radar and guided missile systems of today. Accompanying the rapid advance in electronic theory and accomplishment has been a great revolution in the electro-mechanical design of equipment. Any similarity between the 'breadboard and oatmeal box' construction of the early 1900's and the elaborately equipped television studio of today is strictly coincidental!

In the past ten years an almost explosive rise has occurred in the number of radio and electronics enthusiasts. Three major factors have accelerated this increase: (1) Introduction of the Novice, Technician, and Citizens radio licenses, (2) Availability of elaborate, well-engineered equipment of all types in kit form, (3) The immense popularity of "Hi-Fi" audio equipment, which introduced many individuals to their first taste of "hobby-type" electronic equipment. There must be several hundred thousand individuals in this nation alone having widely varying degrees of desires and skills in electronic equipment construction.

Along with the natural desire to create goes pride in a job well done. Nothing is more disheartening than to spend hours on a project, only to wind up with a malfunctioning eyesore. Frequently this is the result of the lack of proper tools and "know-how."

Both theory and design of electronic circuits have been covered untold times in textbooks, handbooks, and magazines. The story of how to *construct* the equipment and *how to make it work* is another matter that is usually ignored or politely brushed aside.

ELECTRONIC CONSTRUCTION HANDBOOK is designed to supplement, rather than duplicate, other Handbooks and will fill a gap which exists in the field of electronic literature. Most of the ideas, hints, and suggestions on workshop practice contained in this Handbook are the accumulation of years of personal, and often sad, experience! It is the hope of the author that this book will be of assistance to the electronic and radio constructor, and will help him to avoid some of the usual pitfalls in electronics while aiding him to build equipment of which he will be proud!

CHAPTER I

Electronic Construction Practices

Electronics as a creative field for the hobbyist and experimenter is not new. As long ago as 1836 Samuel F. B. Morse developed the telegraph, the first workable means of long distance communication. It used basic electronic principles of which even he was unaware. Forty years later Alexander Graham Bell improved the primitive telegraph system by working out a method whereby the human voice could be transmitted by wire. The original efforts of these men were strictly experimental, with little thought of financial gain. We can truthfully say that these men were some of the first "amateurs" or "hobbyists" in the new and exciting field of electronics.

THE GROWTH OF ELECTRONICS

Technological growth in electronics up to the end of the 19th century was practically non-existent. However, a series of startling discoveries by Marconi and others around the year 1900 sparked the imagination of many of the experimentally inclined, and the real age of the electronic hobbyist began. Although the growing flame was nearly extinguished by World War I, the cessation of hostilities initiated an outburst of interest in experimental radio, fanned by the new craze of "broadcasting."

Prior to World War I most of the developments in electronics (or "wireless,' as it was then known) were carried on in home workshops by a hard core of experimenters. Construction methods were crude, and parts and equipment were largely home-made from materials that could be found in the home or nearby hardware store. Manufactured components were either too expensive or unavailable to the experimenter.

After 1920, when the vacuum tube became generally available, the volume of manufactured electronic components increased rapidly. "Build-it-yourself" kits appeared in the radio stores, and the names of *Colin B. Kennedy*, *Armstrong*, *Stromberg-Carlson*, and *R.C.A.* were household terms to the avid radio experimenter. Neutrodynes, reflex receivers, and bulky superheterodyne sets were the order of the day.

THE "BREADBOARD" RADIO

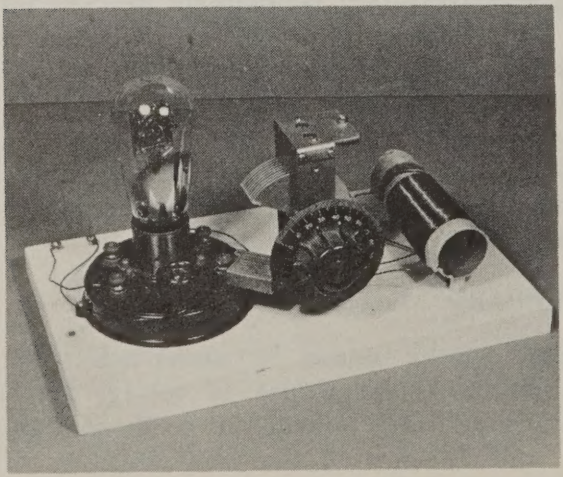
The experimenter of the "twenties" would indeed be awestruck if he could see the impressive radio construction techniques of today. Metal chassis construction as we know it was practically unheard of in those days. Sheet aluminum was unobtainable, and because of the unavailability of manufactured metal ware and the difficulties associated with home fabrication, the famous breadboard form of radio construction was in vogue. Coils were wound on any available form (mailing tubes and oatmeal boxes worked well) and small components were fastened to the wood baseboard with screws or nails. Connections were made under screw heads, or to *binding posts.* Square *buss-bar* wire was popular for low loss construction, and soldered joints and insulated wiring were still uncommon in the early "thirties."

A quiet revolution in radio design took place in the years between the World Wars. The a.c. tube appeared, sounding the death-knell of the storage battery set and "single dial tuning" became common. Construction methods gradually changed, shifting from breadboard style to simple metal foundations having fastenings and cut-outs adapted to mass production techniques. At the same time, sheet metal chassis, boxes, and panels became available to the home experimenter, along with the tools necessary for construction of all-metal assemblies.

World War II started the present trend towards reliability, ease of assembly, and miniaturization. The need for battlefield mobility and ruggedness motivated a great deal of research to find simple, reliable electronic equipment of minimum weight and bulkiness. This trend was further accelerated by the rapid growth of post-war television, and yet more recently by the expanding use of elaborate electronic computer assemblies in the military services and industry.

RADIO COMPONENTS

The individual components that make up electronic equipment are shrinking away to oblivion. As the equipment became more complex over the years the need for more and better components followed. Simple three-tube broadcast receivers gave way to complex 26-tube television sets. Eight-tube aircraft radios were obsoleted by 66-tube multi-channel VHF transceivers. It is interesting to contemplate how bulky a modern television receiver would become if it were built entirely of 1930-model components! The continual refinement and miniaturization of all radio components has prevented the sheer bulk of the modern electronic equipment from suffocating the



"Breadboard" radio was popular in "gay twenties" era. Single tube receiver used battery powered 201A tube in a regenerative circuit. A simple set such as this was often plagued by hand capacity effects and instability. Technological advancements plus use of metal chassis made this style of construction obsolete.

builder and user! Miniaturization of components has not only permitted reduction of equipment size and weight, but has also provided increased efficiency for high frequency equipment which requires short leads and small components. Many of the present day electronic developments would have been difficult, if not impossible, to achieve without profound attention paid to the miniaturization of the individual components.

Using modern components and techniques, the home builder can successfully build circuits and equipment that were expensive laboratory items only a short decade ago.

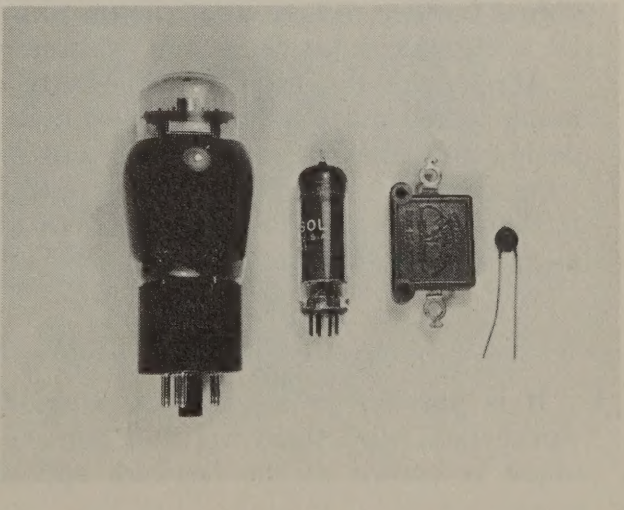
Circuit Radiation

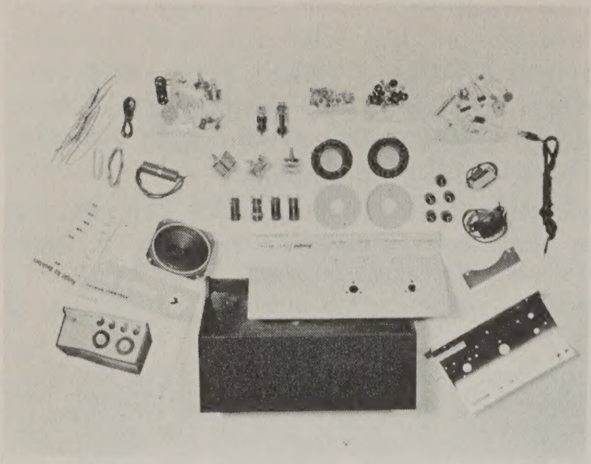
The influence of stray radio fields on nearby electronic equipment was a neglected and unimportant by-product of the radio art in the past. The advent of television, however, has had a major influence on electronic construction techniques, at least so far as amateur transmitters are concerned. The most popular amateur bands are lower in frequency than the TV channels, and *harmonics* (overtones, or multiples of the fundamental frequency) generated by poorly shielded transmitting equipment could raise havoc with nearby TV receivers tuned to the high frequency TV channels. As a result, amateur builders and equipment manufacturers as well have been forced to redesign the transmitting equipment and to take steps to eliminate spurious and unwanted radiations from the electronic gear. Suppression of television interference "TVI" has become a major consideration in the design of transmitting equipment of all types, and elaborate metal shielding and electronic filters are now an accepted part of modern transmitter design.

ELECTRONIC KITS

The increasing degree of complexity of modern electronic equipment often causes enthusiasts to shy away from original design and construction. Even so, there has been a tremendous growth in the "build-it-yourself" type of electronic gear, encouraged by the now famous kit-type equipment. Many reputable firms market electronic kits which include all necessary materials

Component miniaturization permitted radio equipment to shrink to sizes believed impossible a few years ago. Midget 6AQ5 tube and larger, older 6V6G have nearly identical electrical capabilities. Ratings of modern disc capacitor and the old mica unit are identical. Compare the size!





Excellent kits are available which cover equipment of all types! Shown here is the "Knight-Kit" receiver. (Allied Radio Co., Chicago). Kit is complete to hardware and solder. A large, illustrated instruction book makes assembly of kit a quick and easy job. A unit such as this is a good introduction to field of radio and electronics!

for the assembly of a large variety of items such as "hi-fi" audio systems, amateur gear, and test equipment. The kit provides an excellent creative outlet for the hobbyist who is short on experience or time, or who does not have a well equipped workshop, as the design, layout, metal work, and finishing are already completed by the kit manufacturer. It is only necessary to assemble and wire the unit, following step-by-step instructions furnished in the kit. Combinations of home built, kit assembled, and commercial equipment may be used in one installation in the typical amateur station. Radio and TV service benches frequently exhibit such equipment combinations, attesting to the popularity of electronic kits among service organizations.

Build Your Own Kit?

No matter how well an electronic kit has been designed and packaged by the manufacturer, its appearance and performance depend ultimately upon the workmanship and care taken in assembly and wiring. Inasmuch as many kit projects are taken on by beginners with little or no previous construction experience, it is not surprising that the results are sometimes unsatisfactory! The author hopes that this Handbook will provide much valuable information for the beginner as well as the "old timer" to help the individual builder receive a maximum of satisfaction from his efforts—whether he is building a kit or a completely home-made "rig."

Along with the growing popularity of the electronic kit, there are still many hams and experimenters who enjoy the challenges presented in the design and construction of their own equipment. Many others like to build from designs given in magazines and Handbooks. The material presented in the following chapters should be of interest and value to these hobbyists, as well as to the kit builder.

ELECTRONIC ASSEMBLIES

It is possible to assemble a conglomeration of electronic parts on the workbench, wire them up, and achieve a semblance of results. This technique is known as the *haywire* approach and unfortunately has a large

Modern open chassis construction. The major components are mounted atop chassis with small parts and wiring concealed underneath. Controls are placed on front skirt. Public address amplifiers and mobile radio equipment are often built in this manner with addition of removable dust cover to protect above-chassis parts.

following of enthusiasts. However, such a sloppy method has little merit, and it follows that any sensible grouping of components into a workable unit should have some "visible means of support." Numerous methods have been devised for mounting electronic assemblies, and the following (aside from the breadboard-style) are in popular use.

Breadboard Construction

Popular in the "old days," simple breadboard construction is practically obsolete, although temporary experimental circuits that require frequent wiring changes are occasionally built up on simple wood boards. Today's electronic equipment with its high gain audio circuits, tricky VHF techniques, stability requirements, and other complicated factors demands more in the way of a foundation than can be provided by a breadboard, and the sheet metal chassis is in universal use as an inexpensive and satisfactory assembly base for all types of equipment.

Horizontal Chassis Construction

The most common type of electronic equipment assembly makes use of

Chassis and panel construction. This vacuum-tube voltmeter is built on plated steel chassis affixed to an aluminum panel. Such units are often mounted singly in cabinets or stacked in large relay racks and cabinets.

a steel or aluminum chassis on which the major components are mounted. A typical chassis is box-shaped, similar to an inverted baking pan. Small components, such as resistors and capacitors, and the majority of the circuit wiring are concealed within the chassis which provides a measure of shielding, reduces dust accumulation, and makes for a neater appearance. Further shielding and protection are achieved by covering the open bottom of the chassis with a metal plate. Chassis ventilation may be enhanced by large holes grouped around heat producing components. The chassis itself generally serves as a circuit "ground" and where the circuit diagram calls for ground connections these can be made directly to the chassis. Soldered connections are used with steel chassis, and riveted connections are made to aluminum chassis. Common practice calls for one side of both high and low voltage circuits to be at ground (chassis) potential.

A variation of simple chassis assembly is *rack construction* which consists of a chassis-panel combination as shown in the illustration. The assembly can be enclosed in a metal cabinet, or may be mounted in a *relay rack*. Rack-type mounting requires that the panel bear the weight of the chassis, and side brackets are usually employed to give added support to heavy units.

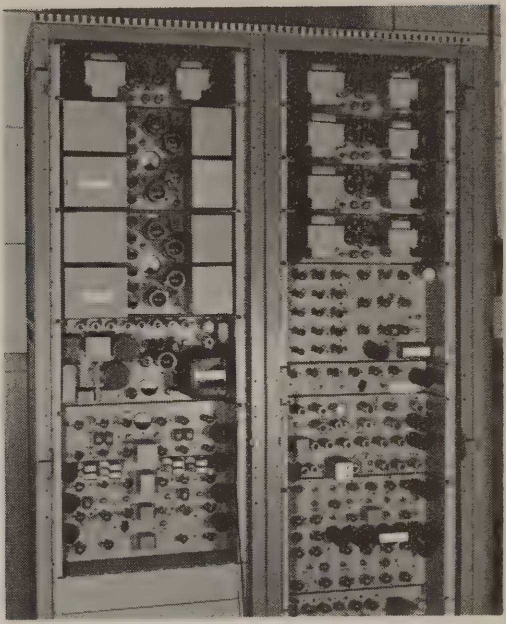
Vertical Chassis Mounting

Several forms of vertical chassis assembly are utilized, especially in commercial practice. The open body of the chassis, rather than the edge, is mounted flush against the back of the vertical panel. One form, *dish mounting*, is very popular in television studio assembles. The chief advantage of dish mounting is that the assembly occupies less depth behind the panel than is the case if the chassis were horizontal. On the other hand, it is usually necessary to remove the assembly from the rack or cabinet for maintenance or repairs, as the components are "sandwiched" between the chassis and the panel. This is a time-consuming task and makes for awkward handling, especially where panel controls are wired into sub-chassis circuits.

A variation of vertical chassis mounting used with military and television equipment places the plane of the chassis in the middle of the rack. All tubes and large components protrude toward the front of the rack. Other components such as small resistors, coils, and capacitors are located on the open back of the chassis. The chief advantage of this arrangement is accessibility. Tubes can be easily identified and reached from the front. At the rear of the cabinet it is possible to perform maintenance and repair or make "in-operation" checks without removing the units from the rack. Both front and back of the chassis are left open for ventilation, and doors on the enclosure reduce the accumulation of dust that would otherwise occur with this type of assembly.

Box Enclosures

In non-commercial practice the chassis or chassis-and-panel construction technique is the predominating practice. The fabrication of small units, however, often incorporates a metal box for support and enclosure. The box acts as a dust cover, an electronic shield, and a protection for the individual components. A simple chassis within the box supports the major



Vertical, rack-mounted chassis assemblies are becoming popular in commercial installations. Maintenance and "in circuit" tests are made easy by this design. (Photo: WJRT, Flint, Mich.).

sub-assemblies, tubes, and heavy transformers and inductors. Smaller boxes may be placed within the cabinet to protect sensitive circuits. Receivers, transmitters, oscilloscopes, hi-fi audio equipment and a majority of amateur gear is constructed in this fashion. The assembly is simple, cheap, and effective, and the outer surfaces of the box or cabinet may be adapted to serve as a decorative enclosure, permitting the equipment to blend in with surrounding objects. Tubes may be changed and replaced through "electrically tight" doors in the top or back of the box, and the bottom plate of the box or cabinet is often removable for easy service and inspection of the under-chassis components.

Printed Circuits

A post-war development is the revolutionary *printed circuit* board (or *etched wiring)* technique. This assembly consists of a thin phenolic panel to one side of which a copper foil has been bonded. Etching techniques remove unwanted areas of foil, leaving strips of conductive material to which conventional components may be soldered or attached. Such an assembly is well suited to mass production techniques for television sets, small radios, etc. A variation of this process is the *encapsulated circuit* wherein networks of resistors, capacitors, and tubes are manufactured in an integral package easily adapted to automation. Advanced forms of printed circuits make use of ceramic wafers employing etched wiring and composite components to provide a completely automated fabrication process.

Printed circuit techniques afford great savings in labor, and offer the advantages of simplicity, durability, compactness, and uniformity. Difficulty of servicing or repairing the delicate wiring of the fabricated circuitry is one of the main disadvantages of this radically new assembly concept.

CHAPTER II

Use and Mis-use of Your Tools

Examine a skilled workman or professional engineer under the lens and you will find an individual who possesses an adequate supply of tools of his trade, plus knowledge and ability to use them to their best advantage. This attribute is not necessarily limited to the vocations, it applies at the hobby level as well. No one can dispute the fact that given the proper tooling, superior results can be achieved in any craft.

Broadly speaking, tools can be divided into two categories. The first group includes the *essential tools* without which a job would be extremely difficult, if not impossible. The second group comprises the *convenient* tools, which permit savings in time and labor or make for improved workmanship. Actually, there is really no sharp dividing line between the groups because of widely varying individual requirements and standards.

Selection of Tools

Before he is tempted to "tool up" his workshop, the electronic hobbyist should decide how far he plans to go into the equipment-building phase. If he is going to limit his activities to kit assembly then, obviously, it would be an unwarranted expenditure to purchase tools which might never be used. It is better to begin with a basic kit of tools, then add to the stock later, in the event of progress into design and construction work.

The cost of tools is an important consideration, and it is often difficult for the experimenter to see justification of the purchase of an expensive tool when a cheaper one would seem to be adequate. Better quality tools, however, are likely to give more hours of useful service per dollar and it is often more economical in the long run to buy them, especially if they are likely to undergo frequent and hard usage.

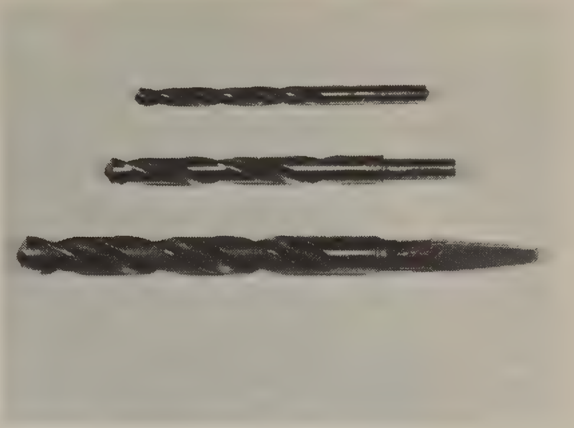
Recommended Tool List

In order to aid home constructors the following graduated tool list has been prepared. It is suggested that the reader consider the list primarily as a guide which can be altered to suit his own personal requirements. The tools recommended for kit assembly are basic for all levels. Examples of the use of the following tools are to be found in succeeding chapters.

Essential Tools for Kit Assembly

Soldering gun, 100 watt (or soldering iron, 100-watt, 3/8" dia. tip).
Solder, 50-50, rosin-core, 1/16" dia.
Long-nose pliers, 6".
Diagonal wire cutters, 5".
Screwdrivers, blade width 1/8", 3/16", 1/4".
Common slip-joint "gas" pliers, 6".

Fig. 1 Top: Standard round shank twist drill. Center: Twist drill with the shank turned down to fit small drill chucks. Bottom: Square shank drill for use in a carpenter's brace.



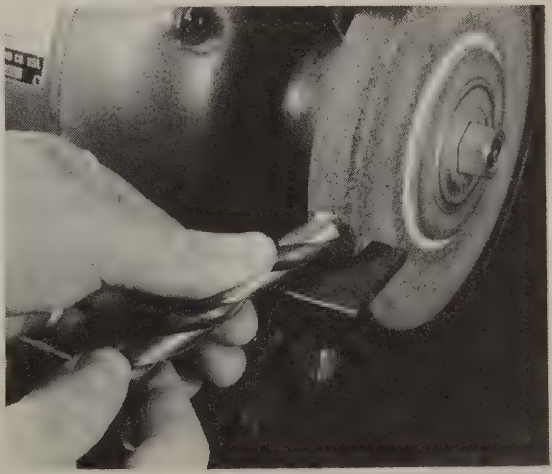
Additional Useful Tools for Kit Building

Adjustable end wrench, 6".
Jack knife, large and small blades.
Soldering-Aid tool.
"Spintite" hexagonal socket wrenches, 1/4", 5/16", 11/32".
Volt-ohm milliammeter.

Essential Tools for Project Construction

Hand drill, or standard duty portable electric drill (1750-2500 r.p.m.), 1/4" chuck.
Round-shank metal twist drills, numbered sizes 1, 10, 18, 28, 33, 35, 42, 50, and 1/4".
Square-shank metal twist drills, 5/16", 3/8", 1/2". (Or round-shank drills turned down to fit 1/4" chuck)
Carpenter's ratchet brace.
Files, small and medium flat mill, half round, round, triangular.
File cleaning brush.
Scriber or scratch awl.
Socket hole punches, 5/8", 3/4", 1", 1 5/32" diameter.
Combination square, 12".
Flexible steel rule, 6 ft. or longer.
Center punch.
Dot, or prick punch.
Hammer, carpenter's, or 1-lb. ball-peen.
Hacksaw frame and blades.
Oil stone.
Coping saw frame and blades (preferably spiral-tooth).
Taper reamer, 3/8" to 1", square shank.
Lineman's pliers, 8½".
Bench vise, 3½" minimum jaw width, swivel base.
Steel anvil block, about 2" x 3" x 4".
"C" clamps, 2" or larger.
Keyhole hacksaw.
Offset, thin, flat end wrench, 1/2 - 9/16".

Fig. 2 Sharpening twist drills by hand requires skill and practice. Good accuracy is obtained when drills are supported on grinder tool rest and light hand pressure applied. Cutting angles of drill should be checked with a drill point gauge.



Additional Useful Construction Tools

Set of miniature flat end wrenches, 13/64" through 3/8".
Set of small Allen wrenches.
Phillips screw drivers, small and medium.
Complete set of "Spintite" hexagonal socket wrenches, 3/16" through 1/2".
Box end wrenches, double-ended, 3/8 - 7/16", 1/2 - 9/16", 5/8 - 11/16".
Wing dividers, 6".
Pilot light bulb remover.
Miniature tube pin straightener.
Outside calipers.
Offset ratchet screwdriver.
Pin vise, or hand chuck.
Screw-holding screwdriver, 3/16" blade.
Wire stripper, wire sizes 22 to 12.
Taper-pin reamers, Nos. 0, 3-0, 5-0.
Machine screw taps, 4-36, 4-40, 6-32, 8-32, 10-32.
Tap wrench, No. 1.
Thread-cutting dies, 4-36, 4-40, 6-32, 8-32, 10-32.
Die holder.
Soldering "pencil-iron."
Tin shears, circle-cutting.
Carpenter's saw.
Tweezers.
Dentist's-style inspection mirror.
Drill-point gauge.
"Vise-grip" or "channel-lock" pliers.
Bench grinder with fine-grit and wire-brush wheels.

Deluxe Workshop

Precision, outside micrometer, 1".
Drill-operated hacksaw.
Circle saws.
Automatic center punch.
Fly circle cutter.
Solderless lug crimping tool.
Electric-drill speed reducer.
Complete set of high-speed, numbered and fractional-size, round-shank twist drills.
Drill press, ½" chuck.
Bottled gas torch.
Metal-turning bench lathe.
Paint-spraying outfit.

Twist Drills

The cutting tool most frequently used (and misused) around the electronics workshop is the *twist drill.* The following are a few fundamentals which might be helpful in increasing drill life and efficiency.

Carbon vs. High-speed Drills

Twist drills are manufactured from many alloys of steel. The most common classifications are *carbon* and *high-speed* drills. The initial cost of the carbon drill is somewhat lower than that of the high-speed type, and the former is usually quite satisfactory for low speed drilling of softer materials such as brass, aluminum, wood, mild steel, etc.

Drill point heating caused by sustained high speed drilling is likely to break down the edges of the carbon drill and for heavy-duty service, the high speed drill should be used. These can usually be identified by the small letters "HS" stamped into the shank near the drill size marking.

Square and Round-Shank Drills

The *shank* of a drill is that part opposite the point and beyond the spiral flutes. Twist drills are available with a number of different shank styles. The two commonly used in the electronics shop have either a round shank of uniform diameter, or a tapered square shank, the latter designed to fit the standard carpenter's brace. (Figure 1.) In electronic construction work

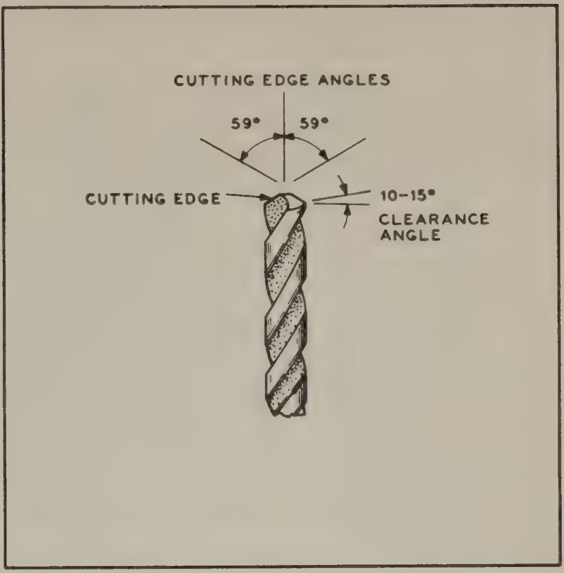


Fig. 3 When properly ground, the cutting edges of a twist drill are equal in length and each forms an angle of 59 degrees with the drill axis. Clearance angle should be between ten and fifteen degrees.

the use of the square shank drill is usually confined to larger sizes which cannot be handled by the chuck of the hand or electric drill.

Necked-Down Shanks

Where the high speed of an electric drill can be tolerated, as in the drilling of wood or soft sheet metals, oversize drills can be used in a quarter-inch chuck. Drills over ¼″ diameter are available with shanks turned down to a quarter-inch. Use of the oversize drill for heavy-duty work is not recommended, however, as such service may result in overheating of the drill motor or damage to its gear train. Projects that involve considerable drilling of large diameter holes are best handled on a drill press.

How to Sharpen Your Drills

The sharpening of twist drills is a job requiring practice and skill if done by hand. Drill-grinding fixtures are available which can be attached to an electric bench grinder, but are seldom employed by electronic hobbyists, as the infrequent need for drill grinding generally does not warrant the expenditure.

The best way for the experimenter to achieve some proficiency at this ticklish job is to practice on a fairly large drill having a factory-ground point. First, of course, he should have at his disposal an electric grinder equipped with a medium-fine wheel. The drill should be held approximately as shown in Figure 2, with the flute (spiral, cut-out portion) against the grinder tool rest. By taking extremely light cuts it is possible to follow the original factory-ground angles and eventually get the "feel" of the operation. Incidentally, it is always a good practice to take light cuts on drills and other hand tools, as heavy grinding is likely to heat and "burn" the edges and result in loss of drill temper.

With frequent light grinding of drill points it is not difficult to maintain sharp edges and proper cutting angles. Figure 3 indicates the correct angles for general workshop drilling. When sharpening a drill it is a good idea to check the point frequently with a *drill-point gauge* (Figure 4). A properly-ground drill will have cutting edges of equal length in addition to the angles shown in Figure 3.

Sharpening very small drills is more critical as it is easy to take off too much of the point before realizing it. Therefore, the advice concerning light cuts assumes even more importance.

THE CARE OF TOOLS

In order to prevent rusting and the accumulation of dirt, the surfaces of your tools should occasionally be given a light oiling then wiped off with a soft, slightly oily cloth. This is especially important if the tools are stored in damp places or are used in humid climates. Many tools have no built-in protection from moisture and can begin to rust in just a few days. After cleaning, a bit of oil should be applied to moving joints and bearings as lack of lubrication can result in eventual wear or corrosion and "freezing" of the joints.

Protecting Sharp Edged Tools

All tools which have sharp points or edges should be protected in some manner in order to avoid injury to the person, as well as to the tool. Damage to (or from) sharp-pointed tools such as awls, scribers, and dividers can be eliminated by sticking the points into corks before storing them in the tool box. One type of scriber has a removable point which can be reversed and stored within the barrel of the tool itself.

Other sharp-edge tools such as chisels, are best kept in racks or stored in boxes or wooden drawers when not in use. Jackknives should be folded before being put away. In order to protect the cutting edges of socket hole punches, they should be kept assembled when not being used.

One of the quickest ways to ruin a pair of diagonal wire cutters is to use them for cutting bolts or hardened steel objects. Diagonals are made specifically for cutting copper wire, and should not be used on other materials except with discretion.

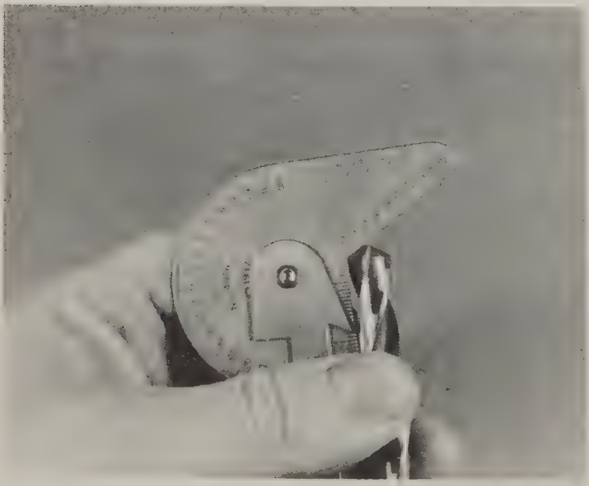
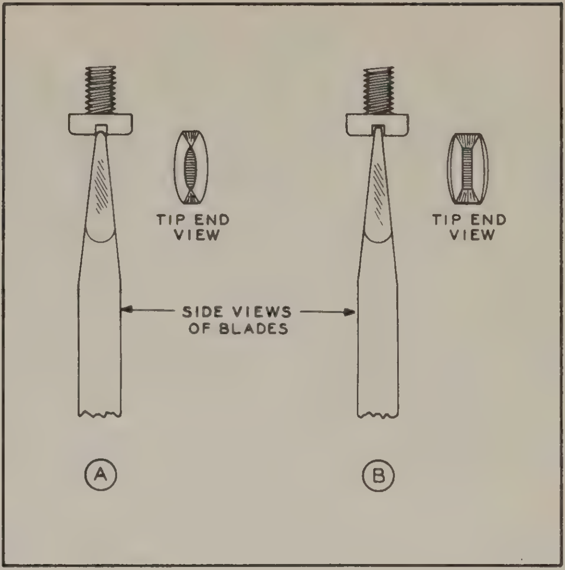


Fig. 4 The drill point gauge serves as a check on both the angle and length of twist drill cutting edges. Accuracy of the work should be checked often when drills are hand ground.

Fig. 5 Screwdriver blade at left shows result of wear or of improper sharpening. Round tip will slip out of the screw slot. At right are side and end views of a properly ground screwdriver blade.

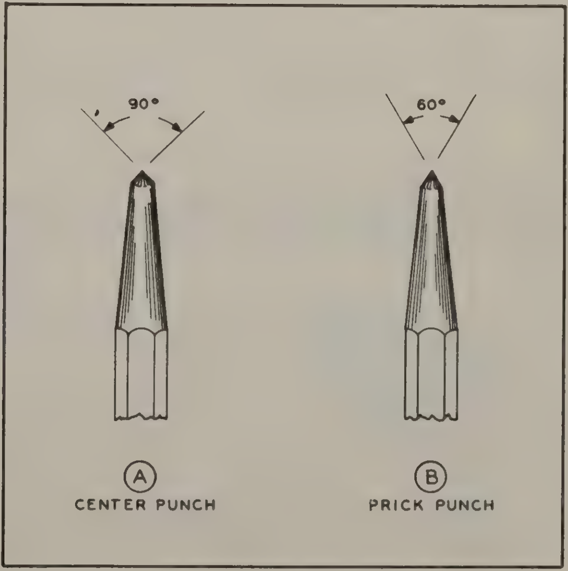


Sharpening Screwdrivers

From time to time the blades of screwdrivers become worn from heavy use, or abuse. When this occurs the screwdriver will often slip out of the screw slot, perhaps resulting in damage to screw heads, adjacent metal surfaces, or the user.

Whenever necessary, screwdriver blades should be given a light dressing on a fine grinding wheel. Figure 5A shows the result of wear or faulty grinding techniques. As you see, the rounded blade does not fit the screw slot well and will likely slip out as soon as torque is applied. In order to prevent this from happening, the screwdriver blade should be sharpened (Figure 5B) with flat or slightly hollow-ground surfaces. The tip should be square and should fit snugly into the slot of the smallest-size screw normally used. The sharp edges along the sides of the blade left by the grinding wheel can be removed with a fine file.

Fig. 6 Tip of center punch (left) is ground to 90° angle. This tool is used for making starting indentations for twist drills. The 60° point on the prick punch (right) permits less conspicuous reference marks in metal surface.



Sharpening Center Punches

Close inspection of the business end of a twist drill will show that it does not come to a point, as one might at first assume. The tip actually forms a sharp edge which is at right angles to the axis of the drill. It is necessary, therefore, to make an indentation in metal-work before drilling in order to prevent the rotating drill from "walking away" from the desired point. A *center punch* is used to mark the starting location. The tip of the punch is ground to an angle of 90° as illustrated in Figure 6A.

A variation of the center punch, known as the *dot* or *prick*-punch (Figure 6B) is ground with a sharper angle of approximately 60°. The prick punch is often used for marking reference points in metal where drilling is not to be done. The sharper tip makes a less conspicuous mark than that of the center punch.

SOLDERING IRONS AND GUNS

Although complex and exotic assembly methods are sometimes employed in commercial electronic manufacturing, most soldering at the hobby level is handled with electric *irons* or *guns*. Broadly speaking, the term "iron" includes all types of soldering tools having rod-shaped tips which are indirectly heated by resistance elements. Most irons require several minutes to reach operating temperatures but will then maintain soldering heat for long periods. This feature is advantageous in extended construction jobs. For general electronic work a 100-watt iron, having a 3/8″ diameter copper tip is most suitable (Figure 7).

A miniature version of the soldering iron, known as the *soldering pencil* is available with interchangeable tips from 1/8″ diameter, up. The smaller tip sizes are very useful for work on miniature tube sockets, printed circuits, and the like.

The term "soldering gun" includes all types of tools which reach soldering temperature within a few seconds. Some have internal resistance elements similar to irons but are faster heating. Most guns operate by virtue of a heavy electric current passing through the wire-like tip. The outstanding feature of the soldering gun is its ability to heat up and cool off quickly, thus making it ideal for service work or short assembly jobs. Constant operation, as might be encountered in major construction projects, may tend to overheat the transformer which is built into the body of the tool.

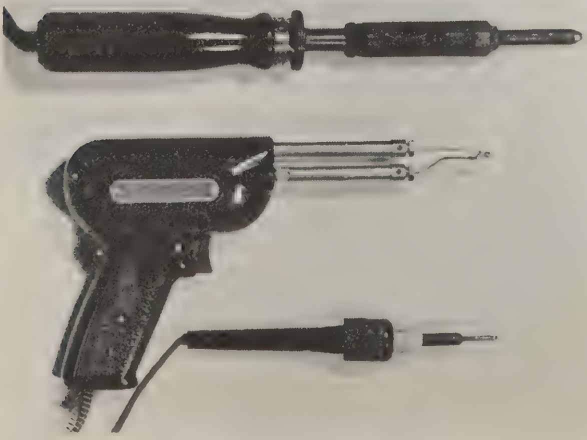


Fig. 7 For heavy work the soldering iron (top) is best. Soldering gun (center) is superior to iron for small assembly work and quick jobs. Soldering pencil (bottom) gets into tight spots in crowded equipment. Use the proper soldering tool for each job!

Care of Soldering Irons

As they come from the manufacturer most soldering irons are pre-tinned ready to use. The ones that are not must be tinned before satisfactory soldering can be done. This is accomplished as follows:

1. Insert the iron plug into an a.c. outlet.
2. Let the iron heat until rosin-core solder rubbed on the tip just begins to melt. When this occurs, coat the flat surfaces of the tip with solder. If heating has progressed too far, the copper will begin to oxidize and darken, making tinning difficult. It can still be accomplished by dipping the hot iron into *non-corrosive* radio-type soldering paste, then tinning immediately.
3. After full soldering heat has been reached, shake or wipe solder from tip.

During construction jobs the soldering iron tip should be wiped frequently with a dry cloth or a pad of steel wool in order to remove the scale-like deposit which forms and to maintain a bright, tinned surface. After each work session it is wise to remove the tip of the iron and shake out any scale accumulation from inside the barrel. This deposit is a result of natural oxidation, and if not removed frequently can build up to the extent where extraction of the tip becomes impossible.

Occasionally it becomes necessary to resurface the tip of a soldering iron in order to remove oxidation-pitting. The tip should be removed from the barrel and clamped in a vise, then dressed down with a large flat mill file, maintaining original tip angles. When pits have been removed the iron must be retinned as discussed previously.

A new soldering iron tip will extend between 2″ and 2½″ from the end of the barrel. If repeated filing has reduced the tip dimension to less than one inch the tip should be replaced as it will tend to overheat. Prolonged oxidation of the tip shank will eventually result in a loose barrel fit and poor heat transfer. This condition also calls for tip replacement. With normal use a soldering iron tip should last several years.

Care of Soldering Guns

The most important factor in the care of the soldering gun hinges on your use of the tool. Power should not be applied to the gun for extended periods as overheating of the tip and transformer may result. Instructions furnished with each soldering gun usually specify the recommended "on-off" time cycle. Soldering gun tips can be renewed several times by filing but not to the extent possible with the soldering iron. After two or three filings it is best to replace the tip using type specified by the manufacturer.

YOUR WORKSHOP AREA

Often the hobbyist has little choice as to the location of his work area. If possible a spot should be selected which has adequate work space and room for storage of tools and equipment. The "climate" should permit reasonably comfortable working conditions throughout the year. If the shop is located in the basement of the home, as is very often the case, excessive humidity may cause rusting and corrosion of tools, electronic assem-

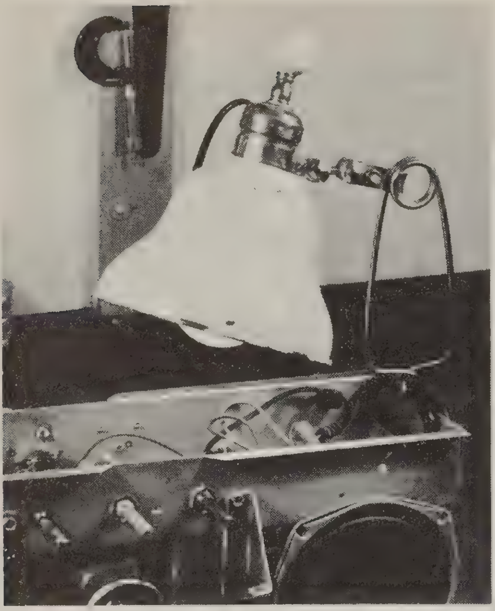


Fig. 8 Poor illumination can have an adverse effect on your workmanship! Portable lamps such as this clip-on unit are available for closeup chassis lighting. Dont ruin your eyes.

blies, and parts. This condition can be reduced considerably by improved ventilation or the use of an electric *dehumidifer.* Dust accumulation is another problem in many workshop areas. This can be minimized by covering equipment with plastic or cloth dust covers, when not in use.

Power Outlets

Many home workshops are deficient in a.c. power outlets. When planning a work area it is wise to include provisions for a sufficient number of outlets for equipment, lighting, and small power tools. One 15-ampere service should be adequate for the average work area. Power tools which are driven by motors of more than one-quarter horsepower are best supplied by a separate 220 volt line, the current rating depending upon motor size. Before attempting to install a.c. circuits, the hobbyist should check local regulations and national electrical codes for proper procedure and to determine the legality of doing his own work.

Electrical Hazards

It is important that precautions be taken against the possibility of electrical shock, especially in basement shops having damp floors or where heating and plumbing pipes pass through the work area. Important safeguards to follow are:

1—Be sure your feet are insulated from the floor. In other words, don't work on electrical equipment while barefooted or with wet shoes on!

2—Pull the power plug before doing repair or construction work on equipment!

3—After power has been removed, discharge filter capacitor in the equipment by shorting positive and negative terminals with an insulated wire. In TV receivers, discharge the voltage which may exist between inner and outer coatings of the picture tube. This potential can sometimes remain for hours after power has been shut off.

4—Before testing equipment with power on, be sure to make a connection from the equipment chassis to an earth ground. (See exception in following note.)
5—Ground the power-tool frame when working on bare earth, damp floors, or if working near grounded metal surfaces.

Note: Some types of electronic equipment are designed without power transformers, and have one side of the power line connected directly to the chassis. This is typical of many so-called *a.c.-d.c.* table-model receivers. It is thus possible for the chassis to be either "grounded" or "hot" to the power line depending upon how the power plug is inserted in the wall outlet. The use of an *isolation transformer*, between the a.c. outlet and the equipment is desirable and is the best way to eliminate shock hazard. In the absence of such protection the presence of line voltage can be checked with an a.c. voltmeter connected between the questionable chassis and ground. If a full line voltage reading is indicated (with power switch "on",) reverse the equipment power plug. This type of a.c.-d.c. equipment, incidentally, *should not* be grounded with a separate connection, as reversal of the power plug will result in a blown fuse unless an isolation transformer is used.

Workshop Lighting

Much poor electronic workmanship is the result of inadequate lighting. Too often the hobbyist "just can't see what he is doing."

Your work area should have adequate over-all lighting. In addition it is convenient to provide additional illumination directly into the work. Several types of adjustable lamps are available for this purpose. Some are

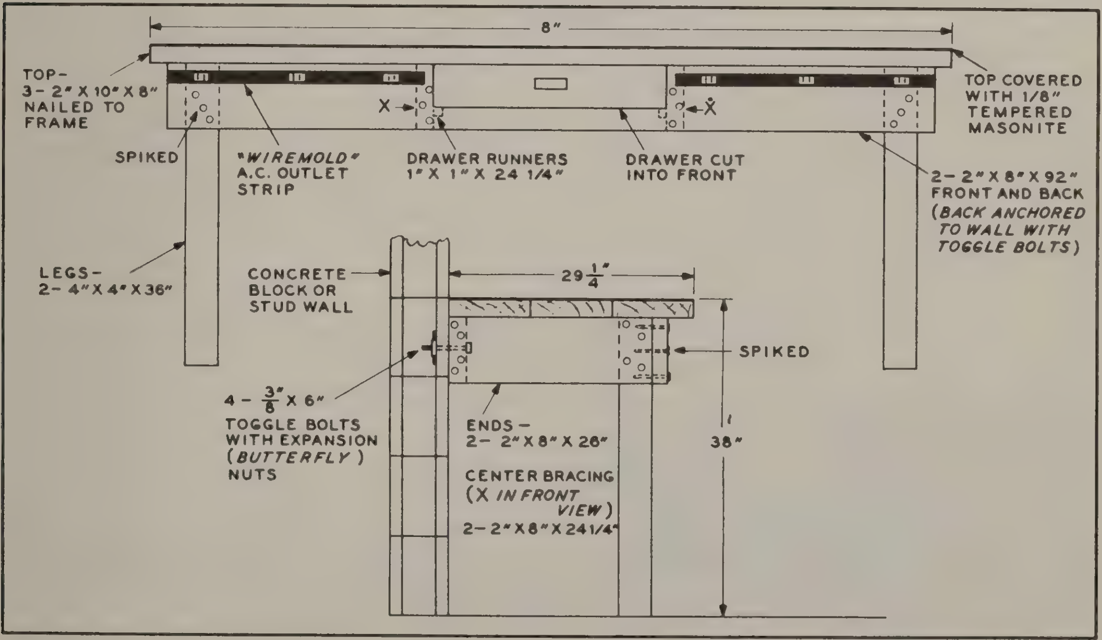

8"
TOP– 3– 2"X 10"X 8" NAILED TO FRAME
TOP COVERED WITH 1/8" TEMPERED MASONITE
X
X
SPIKED
"WIREMOLD" A.C. OUTLET STRIP
DRAWER RUNNERS 1"X 1"X 24 1/4"
DRAWER CUT INTO FRONT
2– 2"X 8"X 92" FRONT AND BACK (BACK ANCHORED TO WALL WITH TOGGLE BOLTS)
LEGS– 2– 4"X 4"X 36"
CONCRETE BLOCK OR STUD WALL
29 1/4"
SPIKED
4 – 3/8"X 6" TOGGLE BOLTS WITH EXPANSION (BUTTERFLY) NUTS
ENDS – 2– 2"X 8"X 26"
CENTER BRACING (X IN FRONT VIEW) 2– 2"X 8"X 24 1/4"
38"

Fig. 9 This workbench is easy and inexpensive to build and will provide lots of working space for big construction projects. The rear frame of the bench is bolted to the wall with toggle bolts. "Wiremold" outlet strips provide plenty of power receptacles. Additional shelves may be built under the bench

equipped with rubber-covered spring clips and can be clamped wherever convenient, even on the edge of the chassis as illustrated in Figure 8. Other types have "goose necks" or adjustable, jointed arms and are designed to be fastened to the work bench.

The Work Bench

Such wide variation exists in individual tastes and requirements, in regard to work benches, that it would be impossible to cover even a small part of the subject here.

Shown in Figure 9 are the details of a typical work bench which will pass any requirements for size and rigidity. Although the design can be varied to suit individual needs, the height and width dimensions are optimum for persons of average size. The bench has only two legs, the back frame member being anchored to the wall with toggle bolts. Where this is not possible, two additional 4 4″ x 4″ legs can be used at the rear.

Be Clean and Systematic!

Although some hobbyists may shudder at the ideas suggested by the above heading, there is a lot of merit to the idea! The following are a few suggestions along this line:

1—Put away all tools, hardware, and parts after each work session. By forming this habit, you will be able to quickly locate any desired item the next time you go to work.

2—Clean up the work area after each job. You may find that missing, irreplaceable piece of hardware in the sweepings! In addition, metal chips from drilling operations can be injurious to linoleum and hardwood floors.

3—Clean up your tools and equipment frequently. Air-borne dust and grease can build up a gummy film over an extended period which is almost impossible to remove.

An excellent way to remove dust from equipment is to employ a dry paint brush, in conjunction with a vacuum cleaner hose. The outside surfaces of equipment can be cleaned quickly and thoroughly by simply wiping off with a damp chamois. A coat of auto-body wax will help to maintain new-looking equipment.

Blowing dust out of equipment with an air jet has merit if it is done out of doors. Inside, however, the process simply serves to move the accumulation of dirt from one place to another, and is not recommended.

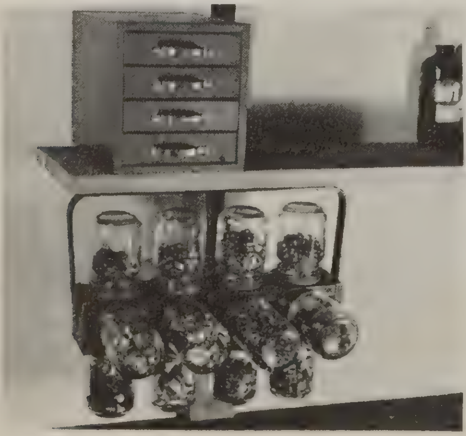


Fig. 10 Small compartmented cabinets and glass jars provide convenient places for storing small components and hardware.

CHAPTER III

Equipment Planning and Layout

The over-all process of creating electronic equipment can be divided into three major operations. These are: (1) *Theoretical design,* which includes development of circuits, drawing of schematic diagrams, and determination of component values. (2) *Physical planning and layout.* (3) *Construction,* including metal work, component mounting, and wiring.

Theoretical design will only be touched upon occasionally in this book as the technical aspects of electronics are covered in the various other text books, magazines, and handbooks. From the builder's standpoint, however, the "practical" phases of equipment planning and fabrication have rarely been considered in sufficient detail. The purpose of this Handbook is to enlarge upon these operations, beginning with the physical planning and carrying through in logical sequence to completion.

The point at which the hobbyist will enter this evolutionary process will depend largely upon his mechanical ability and technical knowledge. Most newcomers to electronics will probably begin with kit-building which involves only the assembly and wiring steps. This is undoubtedly the best policy for the beginner as many of the preliminary construction operations done by the kit manufacturer require considerable "know-how." Some hobbyists, possessing greater experience in the field, may go through the entire creative process working from their own original ideas. A large middle group are those who have the skill to handle their own construction work, but who find it more convenient or desirable to use technical ideas from other sources.

PUT YOUR IDEA ON PAPER

The first step of the design process for a piece of electronic equipment is for the builder to determine the dimensions of the *foundation.* The foundation includes the main supporting components, such as chassis, panel, or cabinet. In addition, it is necessary to know the sizes of the major component parts. Planning can be started even though none of these items are at hand, as their dimensions can be obtained from electronics parts catalogs or manufacturer's specification sheets. If the idea for the proposed project is being taken from a technical publication, the dimensions of the major components may be given in the text. Sizes of other parts and layout dimensions, however, are seldom indicated and these must be determined by the constructor.

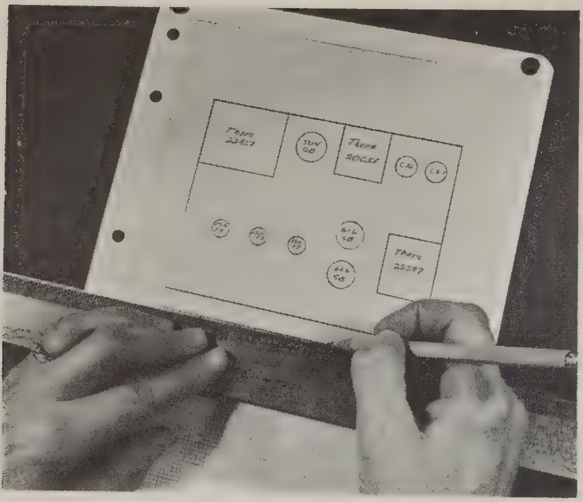


Fig. 1 Accurate layout plans can easily be drawn on 18 x 24 cm. (centimeter) graph paper using a scale of one cm. to the inch.

Hobbyists who plunge into the metal working phase of electronic construction without any preliminary planning are very likely to run into trouble before the job is done. With the possible exception of the very simplest equipment it is wise to proceed by first sketching the general layout idea on paper, trying various layouts until one which appears workable is evolved. The rough plan can then be checked and improved upon by redrawing it to scale. Drafting equipment is not necessary for this job. It can be done with sufficient accuracy on standard 18 x 24 *centimeter graph paper*, using only pencil, ruler, and compass. This paper is inexpensive and can be obtained wherever school supplies are sold (Figure 1). By employing a ruler with a scale of one centimeter to the inch plans can be created for even the largest amateur-type equipment. Although each centimeter square on this graph paper is divided into fifths, it is not difficult to estimate dimensions in terms of inch units. In chassis and panel layouts it is good planning to draw both the chassis and front panel views on a single sheet of graph paper, thus facilitating the coordination of panel and chassis component location. At this stage of layout planning it is only necessary to be concerned with the over-all sizes of parts. Dimensions of mounting holes and cutouts will not be needed until chassis and panel layout operations begin.

Location of Panel Mounted Parts

In chassis and panel assemblies the over-all appearance can often be enhanced by arranging front panel controls symmetrically. Figure 2 illustrates a typical panel layout done in this manner with large control knobs in line near the center, and smaller components along the lower edge. The panel meter, as is the usual practice, is located at the top. When developing such a plan it is wise to work out the locations of panel controls and major chassis components simultaneously, so that front panel symmetry can be obtained without conflicting with efficient layout.

Chassis Clearance

It is not a bad idea while laying out the front panel to locate controls so

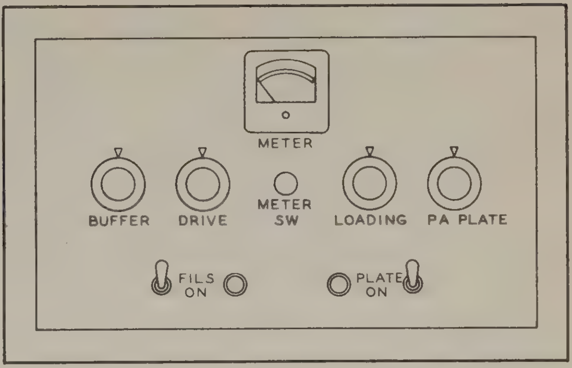


Fig. 2 Front panel layouts are often arranged in this conventional manner. Large control knobs are placed symmetrically about meter centrally located on panel. Small knobs are spaced across lower edge of panel as shown.

that their bodies will clear the surface of the chassis. Mounting controls in the manner shown in Figure 3A would present the builder with additional construction work, as it would be necessary to cut away portions of the chassis top, and possibly the front apron, in order to allow clearance for the controls. Making such cutouts at the edge of a chassis is a difficult process and it is easier and more practical to locate panel controls, as in Figure 3B, so that their bodies are entirely above or below the chassis surface.

Similar problems will be encountered when the bodies of panel mounted controls intended to be located below the surface of the chassis, are found to be larger in diameter than the sub-chassis height. This difficulty can only be avoided by selecting components of small physical size, or by employing a higher chassis, where parts dimensions cannot be reduced.

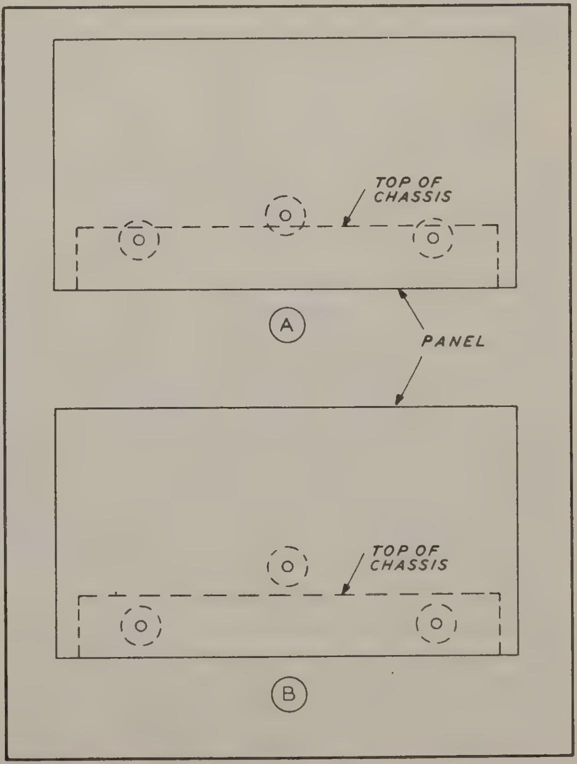


Fig. 3 Panel controls should be located so that components do not fall along chassis edge (A). Chassis cutouts required in this layout are difficult to make and unsightly. Careful location of the panel controls (B) can save the builder many hours of work.

Location of Chassis Mounted Parts

In planning electronic projects the arrangement of chassis components must be tailored to fit each individual situation. Here are a few general principles which can be applied to this task.

The following components are usually mounted on the top surface: large or fully encased transformers, chokes, and filter capacitors; vacuum tubes; large r.f. transmitting coils and variable capacitors; intermediate-frequency (i.f.) and other fully-shielded r.f. coils. Other parts are usually concealed within the chassis enclosure. These include: small resistors and capacitors, small open type transformers, switches, wiring, terminal boards and the like.

Power Supplies

For many years it was customary to locate power supply components apart from associated units. This is still the case where high power equipment is involved or where several assemblies are being handled by a single supply. As far as the hobbyist is concerned, however, most electronic units are designed with an integral power supply. Inasmuch as the supply normally operates without the necessity for frequent manual adjustment, it has become the practice to mount the component parts toward the rear of chassis bases, reserving the front area for functional stages and their respective controls. In the case of a typical audio frequency amplifier, it is very likely that low level audio input circuits will be situated near the front of the chassis. Placement of power transformers and filter chokes at the rear of the chassis will minimize the effects of inductive hum pickup resulting from strong a.c. magnetic fields acting upon the sensitive input circuits.

One objection to rear chassis location of heavy power supply components is that it places the greatest weight farthest from the supporting front panel. This problem can be overcome by using mounting brackets to support the chassis.

STAGE LINEUP AND SPACING

Inspection of the circuit diagram of almost any piece of electronic gear will show that the drawing progresses in an orderly sequence from one vacuum tube or transistor stage to the next. In order to aid wiring, this principle should also be followed in the actual physical layout of equipment.

Spacing between the centers of adjacent tube sockets is not too critical at audio and low radio frequencies, although it should be kept uniform and should allow sufficient space to plug the tubes in the sockets. In the construction of equipment for frequencies above 50 mc, however, many factors which normally can be disregarded at lower frequencies without ill effect, become increasingly critical. It is suggested, therefore, that before attempting to design VHF equipment, the project builder familiarize himself with some of the unusual problems involved by referring to the *VHF Handbook* by Orr and Johnson, published by *Radio Publications, Inc., Wilton, Conn.*

Although it is not always possible or even electrically desirable to achieve symmetry in the layout of chassis components, it is advantageous from the standpoint of appearance to line up or group parts in an orderly fashion. This also facilitates subsequent metal working and wiring operations.

Figure 4 illustrates the application of the foregoing principles in a typical

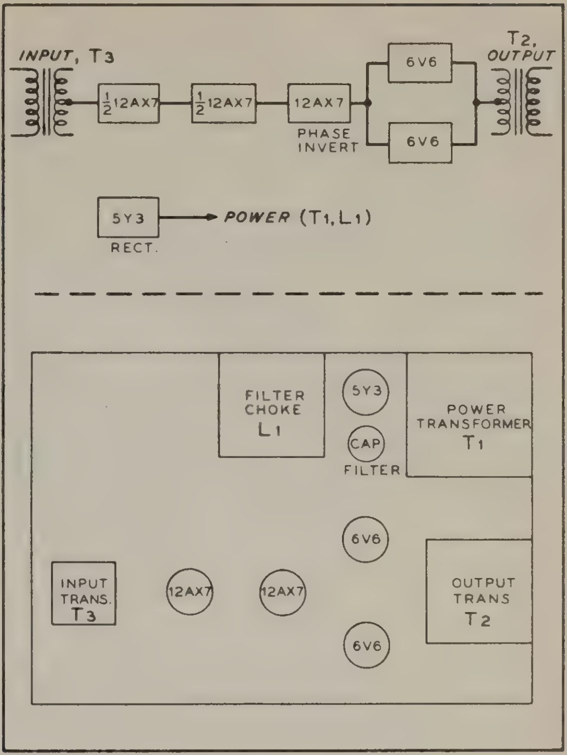


Fig. 4 Component layout on the chassis should bear relation to location of parts in the circuit. Proper component placement will facilitate later wiring operations. Low level stages of this audio amplifier (12AX7 and T3) should be physically remote from hum producing, a.c. field of power transformer, T1.

audio amplifier plan. Note that each stage in the mechanical layout appears in the same order as in the "block" diagram. Observe, also, that the power supply components are located as far as possible from the audio input section. This, incidentally, is imperative in cases where inexpensive uncased audio transformers are used as such units are notorious for susceptibility to inductive hum pickup. Employment of "magnetically shielded" transformers will reduce this unwanted tendency but at a considerably greater financial outlay. In the design of amplifiers having high impedance input circuits where no input transformer is employed the physical separation factor between audio and power supply circuits is much less important.

Shielding

In the construction of audio frequency equipment it is seldom necessary to employ sheet-metal shielding between stages. Such is not the case with r.f. units, however. As a general rule, one should plan for some shielding between successive r.f. stages unless considerable inter-stage spacing exists, or the stages are neutralized, or are operating on different frequencies. Lack of shielding may often result in spurious oscillations and instability.

With the ever-increasing problem of television interference it has become imperative that complete and thorough metallic shielding of the *radio frequency* portions of transmitting equipment be employed. Further information on this subject can be found in subsequent chapters, and in other literature.

Chassis Aprons

Connectors which serve to conduct external circuits into or out of electronic units are usually located on the rear *skirt* or *apron* of the chassis.

Included in this category are such parts as extractor-type fuse holders, terminal strips, power plugs and sockets, feedthrough insulators, coaxial connectors, etc.

In cases where no front panel is employed, operating controls are mounted on the front chassis apron for accessibility. Externally projecting components are very seldom located on the end skirts, however, as it is often desirable to place the equipment side by side with other units.

Layout Principles

Once an over-all plan has been conceived and foundation units and major component parts are at hand, it is time to begin the actual layout operations. The term *layout* refers to the process by which dimensional information is placed upon the sheet metal surfaces in preparation for drilling and cutting.

There are two methods of accomplishing foundation layout. One involves the marking of dimension lines directly on the sheet metal, utilizing sharp pointed instruments such as the scriber and divider. This process is common in industry, and is satisfactory in cases where the bare metal surfaces are to be subsequently finished in paint or lacquer. Most equipment fabrication at the hobby level, however, employs prefinished metal ware, and it is obvious that the direct layout method would result in objectionable surface scratching.

An alternate method which eliminates the disadvantages of direct layout calls for the covering of the foundation surface with paper, the actual layout then drawn on the paper. Where chassis bases are involved apply a continuous length of wrapping or shelf paper to the surfaces, pulling the sheet tightly over the top, front, and rear aprons. Secure the paper to bottom edges with masking tape. Only the front side of panels generally need to be covered. In either case, any overhanging paper should be trimmed at the edges of the metal.

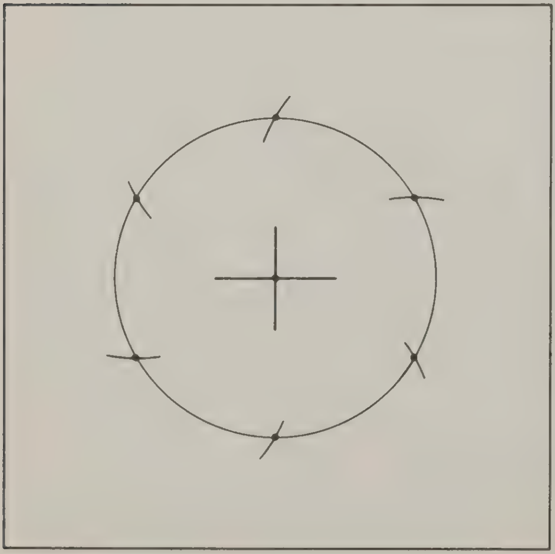


Fig. 5 Radius of circle may be used to divide the circle into three or six equal parts. Mark radius dimension along circumference of circle with a compass or scribe. This layout technique is useful in determining mounting holes for panel meters.

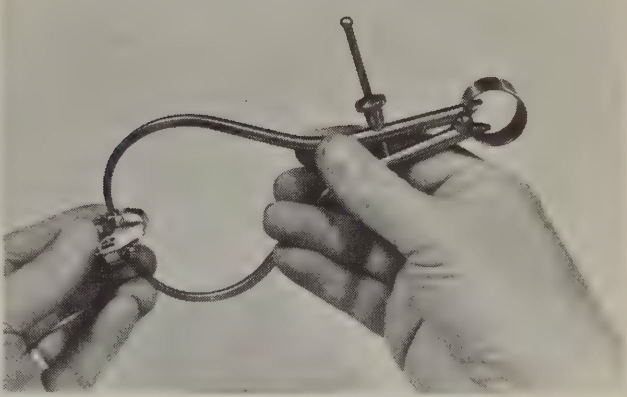


Fig. 6 Outside calipers facilitate measurement of dimension which would be difficult or impossible to determine with ordinary ruler.

Layout Tools

For layout work the following tools are practically indispensable: combination square, flexible steel rule, pencil and compass. Other tools which will make work easier are "C" clamps (2"), divided, outside caliper, scriber, center punch, prick punch (or automatic punch), and hammer. Most of these tools are quite familiar to the hobbyist and their functions are illustrated in Figures 5-9.

FITTING THE CHASSIS TO THE PANEL

In the fabrication of chassis and panel assemblies, the two foundation components will usually be joined into a unit with some components being anchored to both metal surfaces. Thus it is wise to precede layout operations by first fitting the chassis to the panel. By employing the following procedure, precise hole alignment between chassis and panel can be assured:

1—On lower front surface of panel, lay out the centers of the holes that will pass through front apron of chassis. Center punch each drilling point (Figure 8).

2—Attach front apron of chassis loosely to rear of panel with two "C" clamps. Place small pieces of cardboard between. "C" clamps and

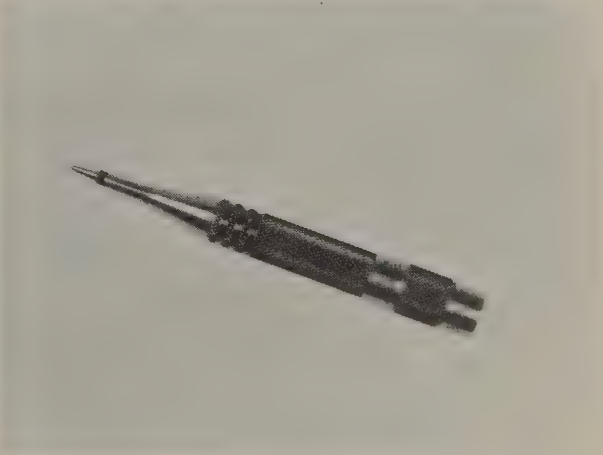


Fig. 7 Automatic spring-loaded center punch is convenient tool to use with aluminum, soft steel.

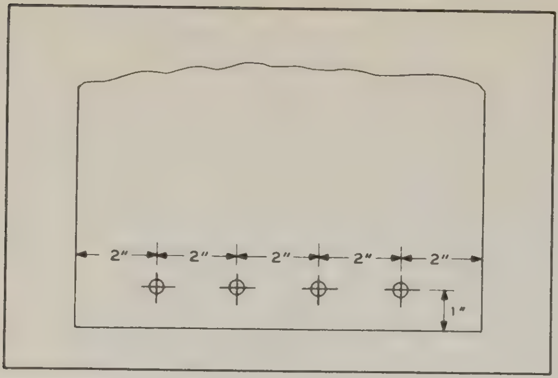


Fig. 8 A combination square is used to lay out these four panel holes. Horizontal line one inch above bottom of panel is center line for controls. Panel is divided into five equal segments. The holes are spaced along the line at regular two inch intervals.

front of panel to protect its finish. Center chassis horizontally on panel and align so that bottom edges are flush. Tighten "C" clamps. (If a chassis bottom plate is to be used it may be necessary to raise the chassis sufficiently above lower edge of panel to allow for the thickness of the plate and mounting screw heads.)

3—At each center punch mark drill small *pilot holes* (about ⅛" or No. 33) through both panel and chassis. Follow up with several successively larger drills until required hole size is reached.

4—Remove clamps and disassemble panel and chassis. Remove sharp burrs from holes with large twist drill or dull jackknife blade. (For further information on drilling and burr removal, see next chapter.)

Cabinet Mounted Units

When chassis and panel units are to be mounted in cabinets or boxes it is very likely that the bottom edges of chassis and panel *will not* be flush. In order to assure accurate fitting of the entire assembly, the following procedure should be used:

1—On front of panel lay out all drilling points common to panel and chassis apron.

2—Center punch each point.

3—Drill pilot holes *through panel only*. Remove burrs.

4—Place chassis in normal position inside cabinet. If a chassis bottom plate is to be employed this should also be in place secured with mounting screws.

5—Fasten front panel to *cabinet* with panel screws. (Sometimes the mounting holes in panels are considerably oversize; therefore the panel should be aligned to its final permanent position on the cabinet before tightening screws.)

6—Reach through open top or back of cabinet and push chassis up against rear of panel, centering chassis horizontally.

7—While holding chassis securely against panel, mark drilling locations through panel pilot holes and on to chassis apron, using sharp pencil (or scriber, in case of direct layout).

8—Remove panel and chassis from cabinet.

9—Fit panel loosely to chassis with "C" clamps. Align panel pilot holes over respective marks on chassis apron. Tighten "C" clamps.

10—Proceed with drilling operations as previously described.

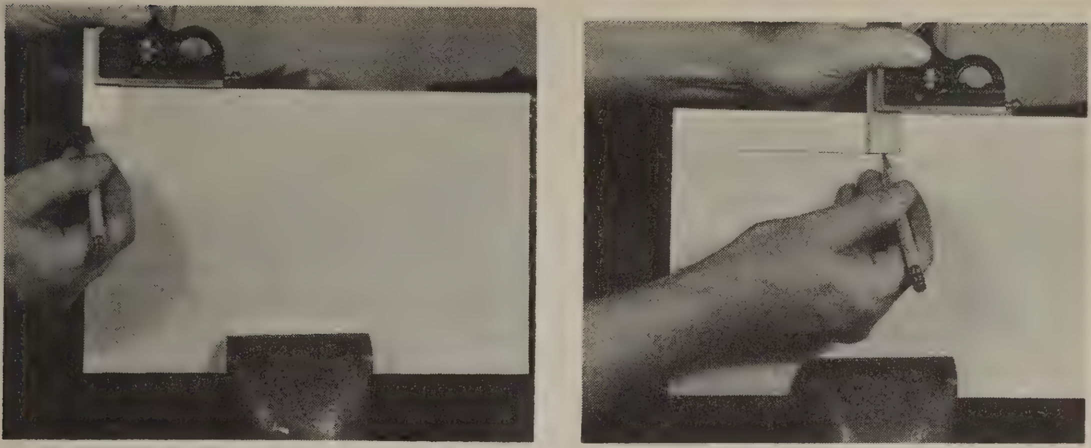


Fig. 9 Square is used to mark parallel layout lines on chassis in order to align marks for mounting holes. Layout is drawn on paper overlay taped to chassis.

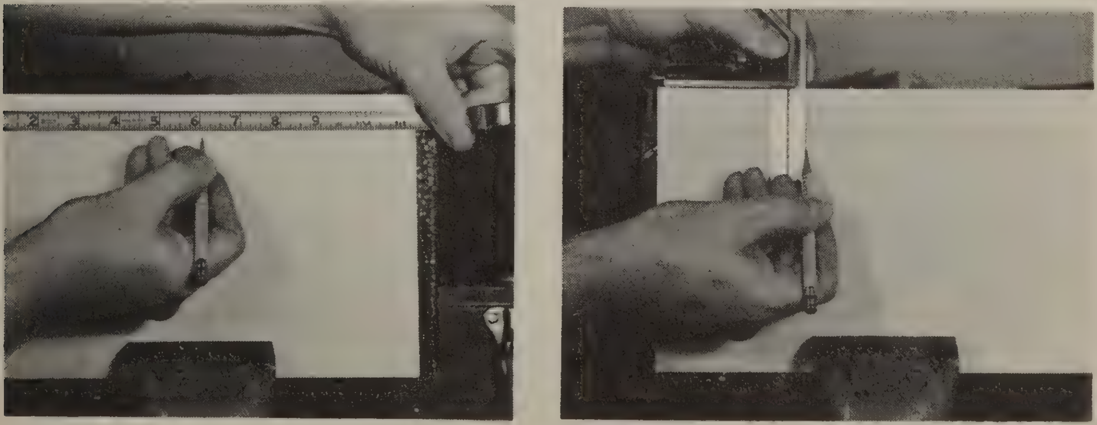
FRONT PANEL LAYOUT

In most cases mounting of panel controls requires the drilling of a single hole for each component. The problem of panel layout, then, will become simply a matter of locating individual reference points in accordance with the original plan. The layout procedure is basically the same as that described under the illustration "Use of Combination Square." The major exception to this rule involves the location of mounting holes for meters.

Meter Layout

The large majority of panel meters (aside from the "edgewise" type) are patterned after one of two basic designs. One style has a round face, with three mounting holes or studs equally spaced around the rim. The second type is fashioned with a square or rectangular face, and is equipped with four threaded mounting studs. Many meters have the studs located near the corners, spaced uniformly with respect to the center of the meter body. Both the round and rectangular varieties have round bodies.

As an aid to layout, manufacturers often furnish with each meter a drilling template or specification sheet. In the absence of such information,



however, the following procedure can be used for locating body and mounting holes. Figure 10 illustrates the dimensions with which the constructor will be concerned.

Rectangular-face Meter Holes

1—Lay out center point of meter body on panel, according to plan *(point A)*. This point must, of course, be located more than one half of dimension *B* (over-all case height) from top edge of panel. Prick punch *point A* at intersection of coordinates.
2—Hold 45° edge of combination square head against top edge of panel and position square so that edge of rule touches *point A*. Draw diagonal *line H*. Reverse position of square and draw *line J*.
3—Determine exact distance between centers of diagonally opposing mounting studs. Set compass point spacing to one-half this dimension. Place point of compass in punch mark at *A* and strike arcs to intersect diagonals at *D, E, F* and *G*. Recheck accuracy of dimensions by comparing with stud measurements on meter. Center punch the four points.
4—If layout paper is being used on panel, tear out a section a bit larger than area of meter body.
5—Measure diameter of round meter body. Set *divider* points to one-half this dimension, plus 1/32″. Scribe *circle C* directly on panel, cutting in deeply enough to provide guide for later cutting or sawing operation.

Round-face Meter Holes

The layout procedure for round-face meters is somewhat different from that of the square variety, as only three mounting screw holes are involved. Refer to Figure 11:

1—Lay out center point of meter at *A*.
2—Place 90° edge of combination square head against top edge of panel. Align edge of rule at *point A*. Draw perpendicular *line F* from top of panel.

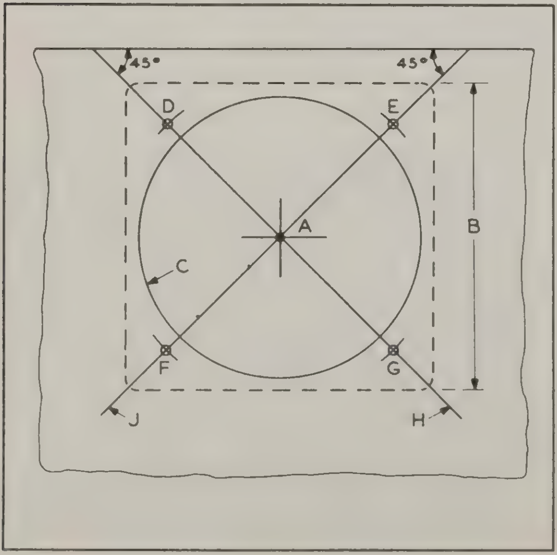


Fig. 10 Square face meter requires a large body hole and four small screw holes. Text explains layout.

3—Measure exact dimension between centers of any two mounting holes or studs in rim of meter. Multiply this dimension by the factor 0.58. The product will be the radius of *circle G*. Set compass spacing to this radius and scribe *circle G*. The intersection of *circle G* and *line F* will determine location of top mounting screw hole.

4—Without changing compass setting, divide *circle G* into six equal segments, starting at *point C*. Alternate points of intersection at *D* and *E* will be locations of other two mounting screw holes.

5—Check spacing between points *C, D* and *E* against actual meter measurements. If dimensions agree, center punch the three points.

6—Scribe *circle H* (diameter of meter body) in same manner as that described for rectangular-case meter. *(Circle B* indicates outside diameter of meter face.)

CHASSIS LAYOUT

There is really no limit to the number of possible variations in the design of electronic assemblies. The best way to illustrate some of the basic chassis-layout principles is to present a typical case study. With this in mind, let us use the audio amplifier design previously shown in Figure 4 of this chapter as a guinea pig. The associated layout plan is given in Figure 12, with critical dimensions being indicated by letters, rather than specific measurements. All of the layout practices which follow are sufficiently general to be applicable to other cases.

Although it is possible to lay out electronic equipment utilizing other methods the work can generally be done most accurately and simply by referring all dimensions to the *physical centers* of the component parts. This holds true because of the fact that most electronic components are designed with their mounting holes uniformly spaced with reference to their centers.

Observe the basic pattern in Figure 12. A good portion of the layout can be done in reference to only two straight lines. One of these, *line Y*, drawn from the rear of the chassis to the front, passes through the center of the 5Y3 rectifier socket, the filter capacitor, and both 6V6 amplifier tube

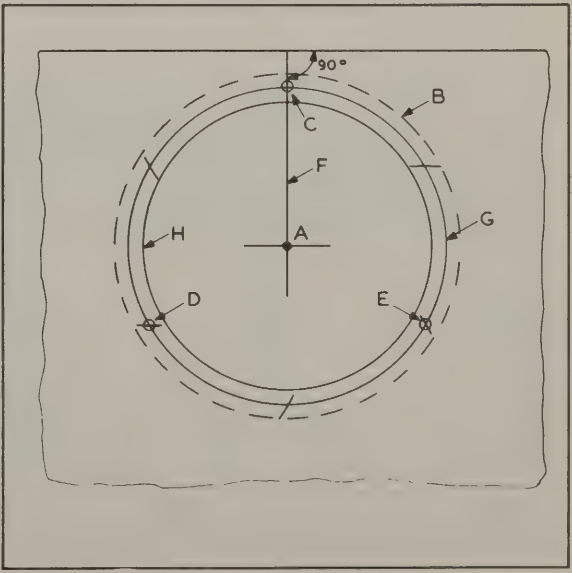


Fig. 11 Round face meter requires a large body hole and three small screw holes. See figure 5 and text for placement of the screw holes.

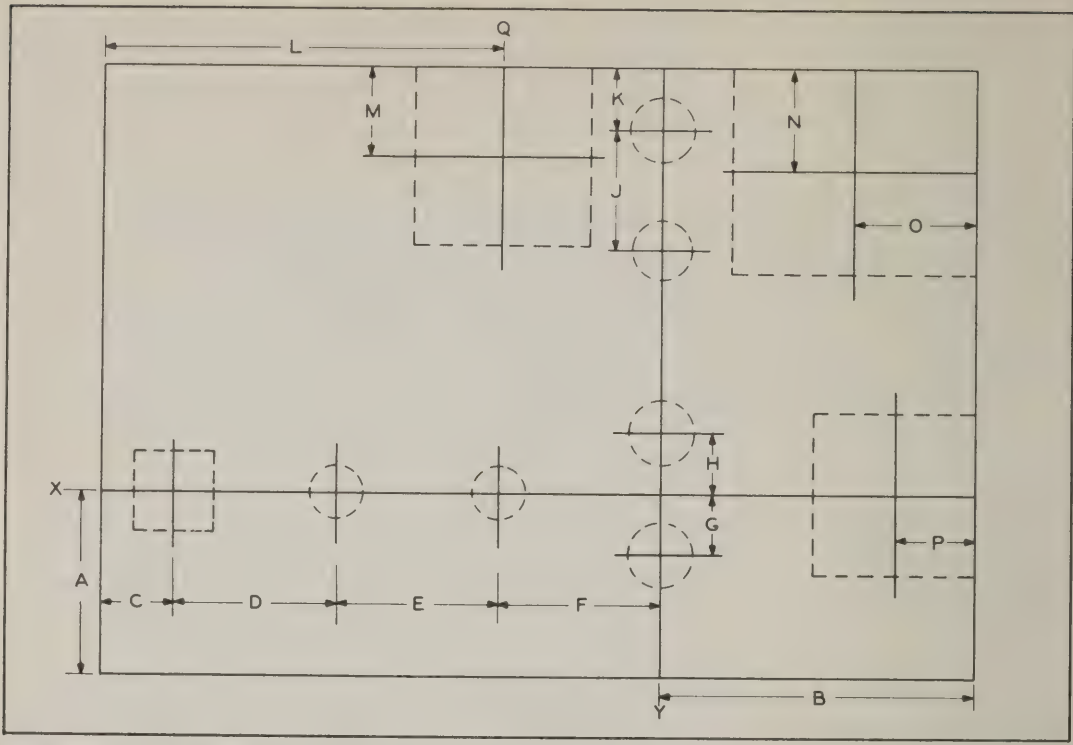


Fig. 12 In a well planned layout components are located uniformly and placed with reason rather than being scattered haphazardly over the chassis. Layout of this chassis is designed around the two intersecting lines, X and Y.

sockets. The other coordinate, *line X*, which is perpendicular to *line Y*, intersects the centers of the input transformer, T3, the two 12AX7 tube sockets, a point equidistant between the 6V6 tube sockets, and the output transformer, T2.

Component Center Lines

In summary, the initial step in chassis layout is the location of component centers. Referring to Figures 12 through 14, proceed as follows:

1—Set 90° edge of combination square head to point on scale corresponding to dimension *A*. Draw *line X* across full length of chassis in manner shown in Figure 13.

2—Reset square to dimension *B* and draw *line Y*, using same method.

3—Using flexible rule, or scale on combination square, mark off dimensions *C* through *K* on *lines X* and *Y*.

4—Extend intersecting lines through points just made, using square. (Figure 14).

Transformer Centers

In this example, power transformer T1, output transformer T2, and filter choke L1 are all to be mounted with their sides flush with the edge of the chassis. Therefore, dimensions *M*, *N*, *O* and *P* in Figure 12 will be exactly *one-half the over-all dimensions* of the components involved. For example, power transformer T1, has outside dimensions of $3\frac{1}{8}''$ x $3\frac{3}{4}''$. Coordinate center lines should thus be drawn 1 9/16″ and 1 7/8″ from the rear and

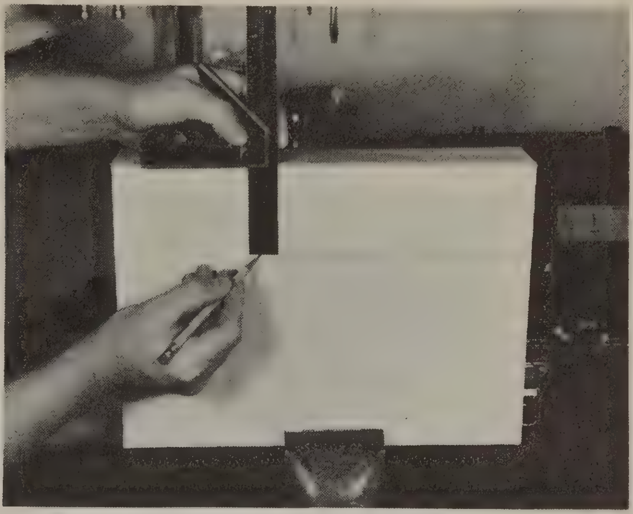


Fig. 13 Main layout line (see "X" of Fig. 2) is marked on paper overlay with square.

right-hand edges of the chassis, respectively. If the plan had called for a margin of, say, ½″ between the edges of the transformer and chassis, dimensions *N* and *O* would then have been 2 1/16″ and 2 3/8″ respectively.

Two Hole Mounting Layout

Most of the smaller chassis components involved in electronic construction projects are provided with two mounting holes which are almost always diametrically opposed, and spaced equally from the center of the part. Included in this group are such things as tube sockets, two hole mounted transformers, filter capacitor mounting plates, and i.f. transformers. In our example this would apply to all tube sockets, filter capacitor C1, and filter choke L1. The layout procedure is very simple:

1—Measure distance between centers of mounting screw holes.
2—Set pencil compass to one-half this dimension. Using center line intersections as compass center, strike arcs across center lines, as illustrated in Figure 15.
3—In addition, in the case of a transformer or a choke measure distance from center of transformer base to center of lead hole. Set compass

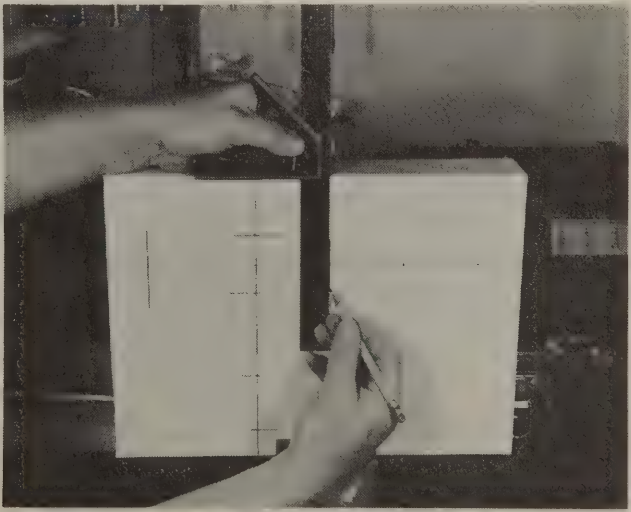


Fig. 14 Center lines are drawn for the sockets and transformers. Next step is to mark component mounting holes.

to this dimension and strike a third arc to indicate location of lead hole in chassis.

Four Hole Mounting Layout

A large proportion of the heavier component parts, and a few of the smaller ones as well, are designed to be assembled to the chassis with four fasteners. Transformers T1, T2 and T3 of our model fall into this category. In a few instances the mounting holes (which are usually located at the corners) form perfect squares. In such cases the layout can be accomplished in the same manner as that described previously for square face panel meters. Input transformer, T3, is a typical example of the foregoing, and the method of layout can be observed at the lower left-hand side of Figure 15.

In order to illustrate the general layout procedure for four hole mounted components, consider the most difficult example in our typical project, power transformer T3. This particular style of unit (illustrated in Figure 16) is commonly known as a *double half-shell* transformer. It is normally placed atop the chassis, with the half shell containing the lead outlets projecting down through a large rectangular hole cut in the chassis.

Critical dimensions involved in the layout for the transformer are: Overall width and length, mounting screw centers, and chassis cutout size. Refer to Figure 17 during the description of the layout procedure:

1—Use *point A* as a center for striking all arcs called for in the following steps. Location of this point was previously described under the heading "Transformer Centers."

2—Measure distance between centers of mounting screws *P* and *O* on transformer. Set compass to one-half this dimension. Strike *arcs G* and *J*.

3—Reset compass spacing to one-half dimension *P-Q*. Strike *arcs F* and *H*.

4—Determine length and width required for rectangular cutout. Using one-half of these dimensions, as before, strike arcs *B*, *C*, *D*, and *E*.

5—Position square as illustrated in Figure 18, so that edge is tangent to arcs at points of intersection with center lines. Draw intersecting coordinate lines at all points shown in Figure 17.

Mounting hole layout for the output transformer T2, or practically any other type of component which requires uniform, rectangular, four point assembly will be identical to that described for the power transformer,

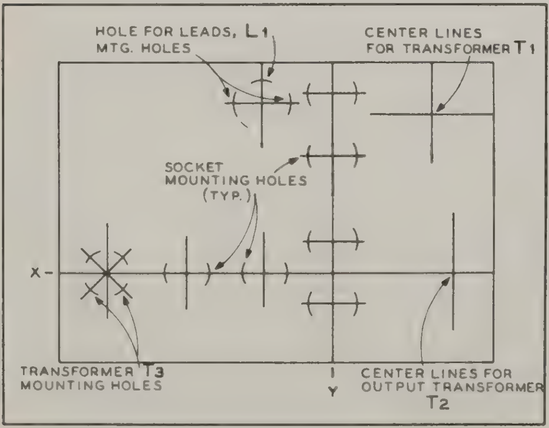

HOLE FOR LEADS, L1
MTG. HOLES
CENTER LINES FOR TRANSFORMER T1
SOCKET MOUNTING HOLES (TYP.)
X
TRANSFORMER T3 MOUNTING HOLES
Y
CENTER LINES FOR OUTPUT TRANSFORMER T2

Fig. 15 After main components have been located on the chassis, mounting holes are marked on the layout. Most small components require two mounting holes spaced equidistant from the center of the component.

except that smaller holes for leads or terminal lugs may replace the large chassis cutout.

LAYOUT OF PANEL CONTROLLED, CHASSIS MOUNTED PARTS

Certain panel controlled parts used in electronic assemblies are designed to be mounted on the chassis. Foremost among these are the larger variable capacitors used in radio frequency equipment. In many cases the mounting of such parts will require the use of spacers, brackets, or standoff insulators in order to bring their shafts up to proper panel height. This usually will have no effect on the location of chassis mounting holes.

In order to assure accurate shaft alignment with the panel hole or bearing, the layout of chassis mounting points should be accomplished in the following manner:

1—Lay out all drilling points on panel according to plan. Drill pilot holes at each location designated.
2—Fit panel to chassis, as described earlier.
3—Using combination square, as shown in Figure 19, find the point directly below the center of the pilot hole involved. Mark this point on the chassis.
4—Position square as shown in Figure 20 and draw a line on the chassis from the point located in step 3 perpendicular to panel.
5—Disassemble chassis and panel.
6—Determine distance from rear of panel to center of component part when properly positioned on chassis. Draw center line, parallel to panel, through this point.
7—Lay out component mounting holes, using appropriate method previously described under "Chassis Layout."

Subchassis Layout

Although the exact location of subchassis parts is usually not critical, it is sometimes necessary to accurately mark drilling points for components

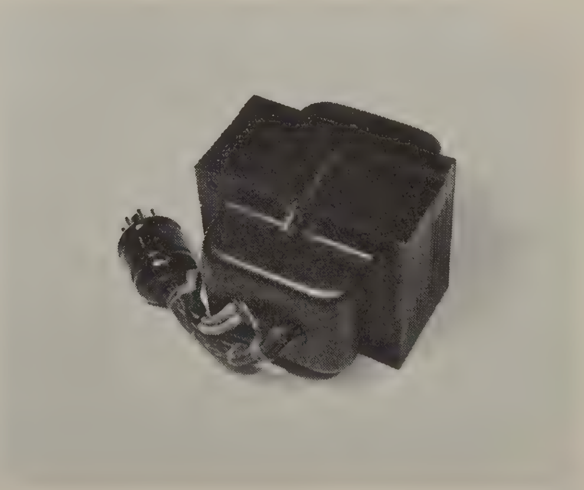


Fig. 16 The "shell type" power transformer requires a large rectangular cutout, plus four screw holes. It is mounted in a horizontal position atop the chassis. Vertical core transformers are easier to mount.

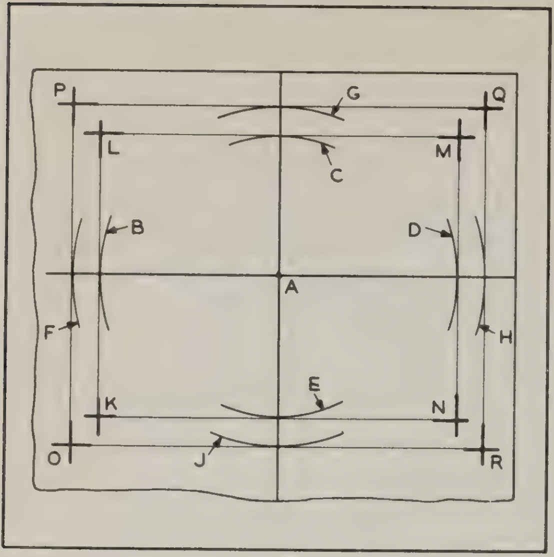


Fig. 17 Four hole mounting layout. Large components, such as transformers and chokes have mounting holes located at corners of a rectangle. See text for layout.

to be mounted under the chassis surface or on the inner sides of skirts. In addition to the difficulty in accomplishing subchassis layout it is usually troublesome to drill from the inside of the base, especially near the corners. The simplest solution to this problem is to make the initial measurements with divider or flexible rule, then transfer the dimensions to the outside of the chassis, where layout can then be done in the normal fashion. This is illustrated in Figure 21. Where precision is important, the thickness of the metal must be added to the internal measurements for outside layout purposes.

Identifying Hole Sizes

One of the final steps to be taken before actual metal work is started is the marking of hole sizes on the foundation components. If the layout has been done on paper, the identification can be accomplished with a pencil. In the case of direct layout on bare metal drill size markings can be done with a wax "china-marking" pencil or crayon. Where direct layout mark-

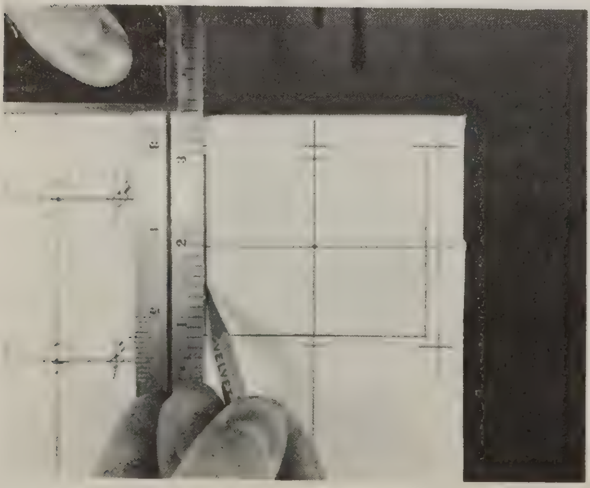


Fig. 18 Four hole square cutout is required for some power transformers and may be laid out with ruler, compass and square as explained in text.

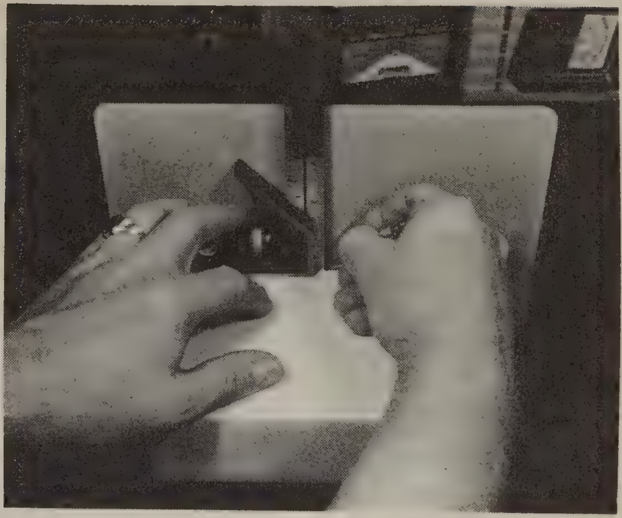


Fig. 19 Center line of panel mounting holes is transferred to chassis in order to insure the proper shaft alignment.

ings are to be more permanent, they can be put on in black paint, using a small brush. Proceed with identification as follows:

1—Determine size of screws to be used for assembly of each part. Circle each drilling point indicated on the chassis and identify with the appropriate drill size number.

2—Determine punch size necessary for tube socket holes. Mark each socket hole center accordingly.

3—Determine and mark drill or punch sizes required for all other components, such as panel bushings, feedthrough insulators, transformer lead holes, rubber grommets, etc.

TRYOUT

With the completion of layout and hole identification, our typical chassis will now appear much as Figure 22. The final step in this stage of equipment design will involve the center punching of layout points in preparation for drilling. Before taking any such action which cannot easily be retracted, the accuracy of the layout should be tested by placing all components on the chassis in their final positions. The following conditions must be met:

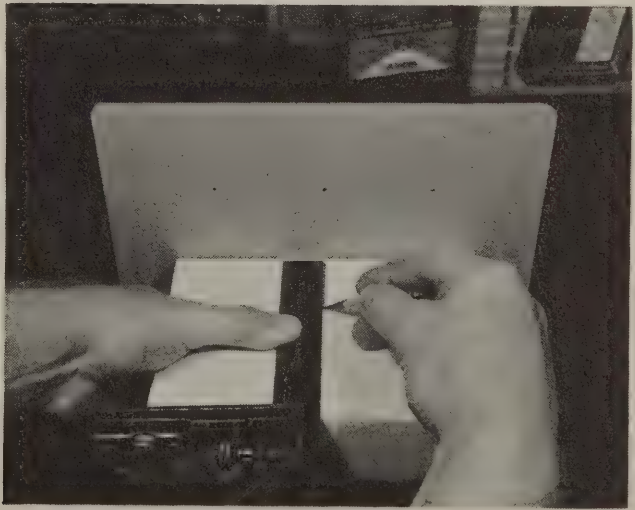


Fig. 20 The panel center line is marked across chassis with a square.

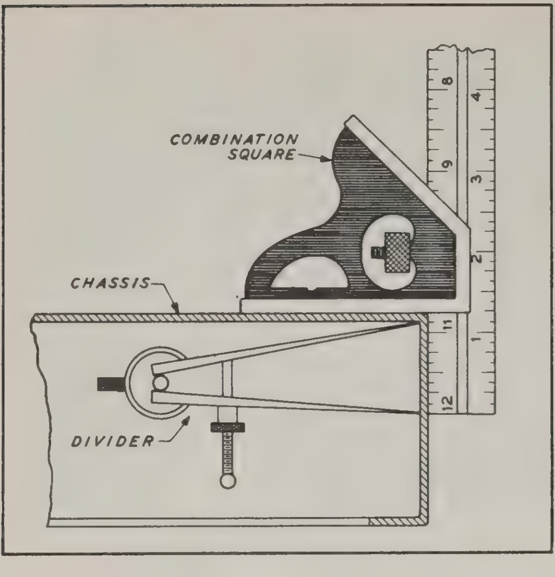


Fig. 21 Layout and drilling are facilitated if inside-chassis measurements are transferred to the outside. Distance is measured by a divider and transferred to the combination square. Thickness of metal should be added to inside dimension as shown.

1—All layout points should be aligned with mounting holes of components.
2—Location of chassis supported parts should not conflict with each other or interfere with the proposed locations of panel mounted components, or their shafts.
3—Shafts of chassis mounted parts, having panel controls, should be in alignment with panel holes or bearings.

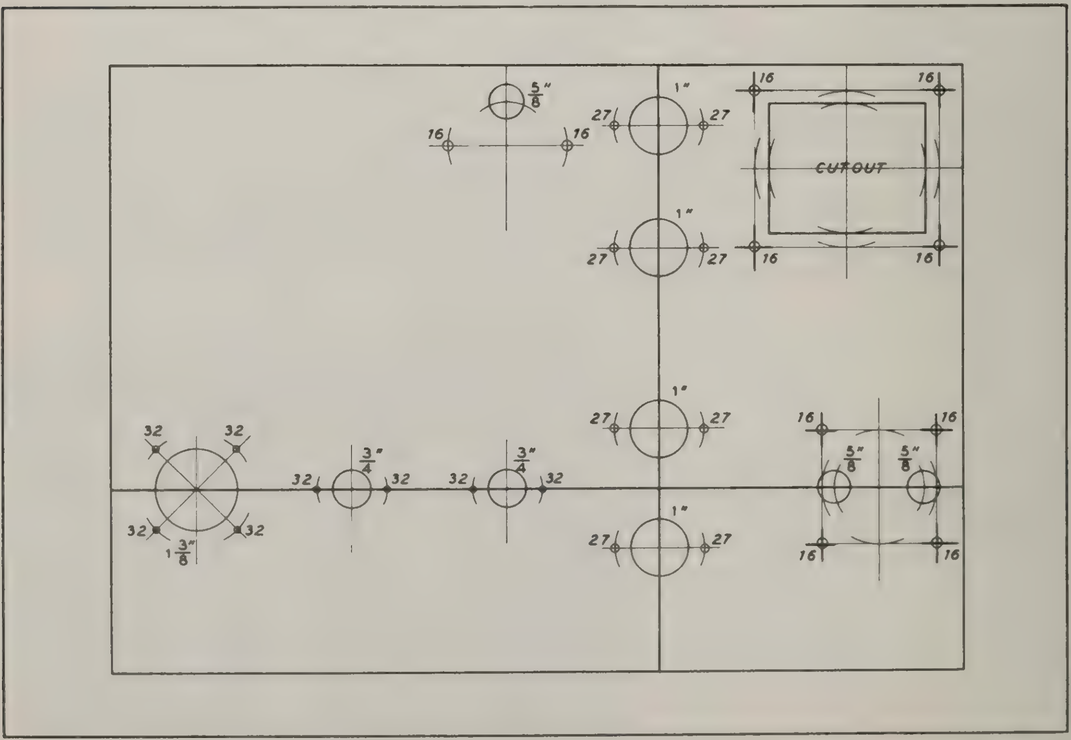


Fig. 22 After layout work is completed the chassis is ready for drilling. The finished layout appears to be covered with a jungle of information, but all of it is important and will make your work a lot easier than the cut-and-try way!

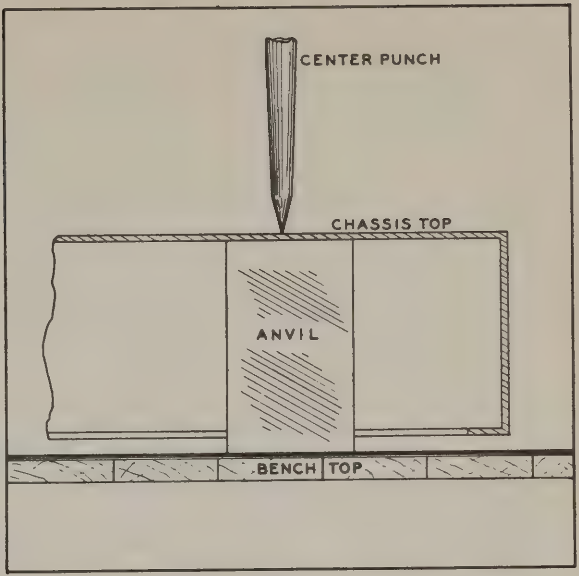


Fig. 23 Support your chassis with an anvil or wood block when you use a center punch to prevent the chassis from being warped, dented.

Reference Marking

Referring back to Figure 17, it will be noted that the intersection of coordinates at *points K, L, M, and N* represent the four corners of a rectangular cutout which is to be made for the power transformer. During the center punching operations, these four points, plus any others which are to be used for reference only, should be marked lightly with the sharper *prick punch* (Figure 23).

RECTANGULAR HOLE LAYOUT

Large, rectangular shaped holes are often required in chassis bases to mount various components. In cases involving parts such as half-shell power transformers, the cutout corners must be square, or nearly so. The fabrication of square-cornered cutouts can be easily accomplished by one of the following two methods: (1) punching each corner, using a *square* sheet metal punch, or (2) drilling of 3/8″ to 1/2″ round hole inside each corner. The second method is most common, as few home builders are fortunate

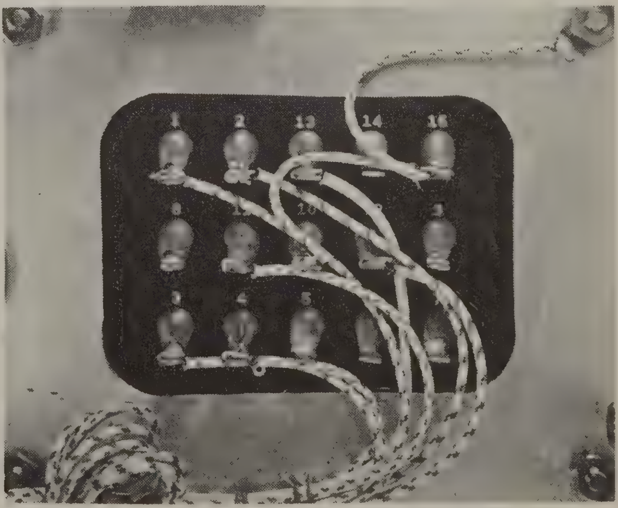


Fig. 24 If square corners are not required in a rectangular cutout, round corners can be cut at less expenditure of technician's effort!.

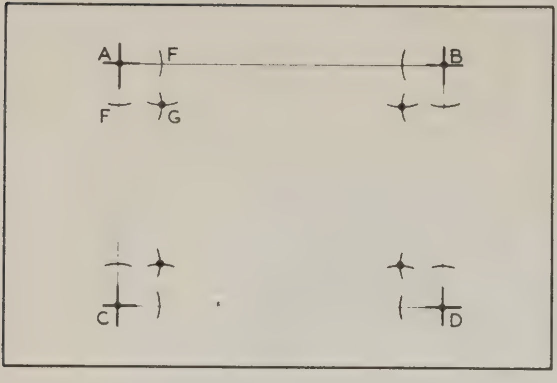


Fig. 25 Rectangular hole layout. Round corners are cut and these must be "nibbled" out to form a square corner. Refer to text for the correct sequence.

enough to possess square sheet metal punches. In either case the work is completed with hacksaw and file.

Where square corners are not required drill or cut round holes and save yourself a lot of hard work. The making of round corner cutout involves the punching of a hole inside each corner with a *round* socket hole punch (Figure 24). The remaining straight edges are then cut out with a hack saw and finished with a flat file. This process produces a neat job, with somewhat less physical labor than is required for the square corner version. Regardless of type of corner, however, the layout of drilling points is similar (Figure 25).

1—Mark *points A, B, C,* and *D* lightly, with prick punch.
2—Determine dimensions of drill or punch to be employed at corners. Set points of pencil compass to one-half the diameter of drill or round punch (one-half the width of square punch).
3—Using *point A* as a center, strike *arcs E* and *F.*
4—Using intersections at *points E* and *F* as centers for compass, and using same setting, strike two arcs to intersect at *point G.*
5—Repeat operations at all corners.
6—Center punch the four locations represented by *point G.* Do not center punch any other points.

CHAPTER IV

Metal Working

Following the completion of preliminary planning and layout, the builder moves to the actual construction processes, which include metal working, component assembly, and wiring. This chapter will be devoted to the details of sheet metal working, plus a few tips that will be helpful to the home-brew artist.

STANDARD SHEET METAL WARE

In the early days of radio and electronics, builders frequently fashioned their own chassis and panels. Now, however, low cost manufactured foundation components are available in such a wide variety of shapes and sizes that it is seldom feasible for the hobbyist to do his own sheet metal fabrication. During the past decade metalware manufacturers have developed a standardized line of components, including panels, chassis bases, cabinets, brackets, boxes, amplifier foundations and other items particularly adapted to electronic assemblies.

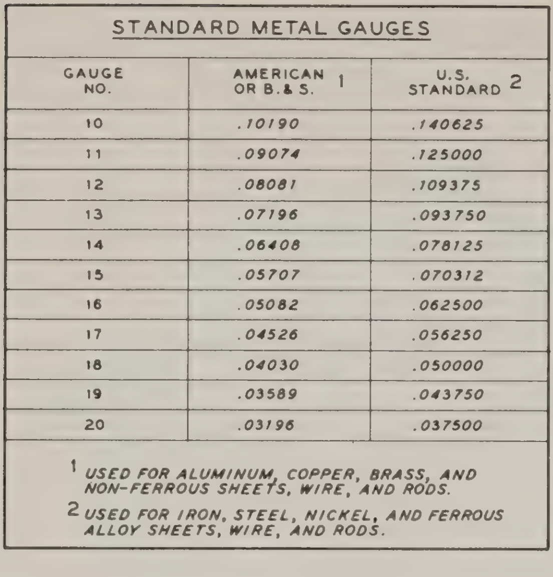
Materials and Finishes

All standard sheet metal parts are fabricated from aluminum or cold-rolled steel. Both materials have their advantages, but from the standpoint of the home builder aluminum is superior. Steel, being harder and tougher, is more difficult to punch, cut, and saw, than is aluminum. In addition, uncoated steel components will rust and thus must be protected by some kind of a finish. Aluminum, on the other hand can be left bare if desired.

The very thing that makes aluminum best for hand tool working (softness) can be a disadvantage, for the metal can be easily damaged by careless handling. In addition, the builder who would like to finish aluminum in lacquer or enamel finds the metal must be "primed" for proper paint adherence. Several approaches to the latter problem will be discussed in a later chapter.

Sheet metal foundation components can be purchased as standard catalog items in different finishes. These include: Black or gray *wrinkle* or *crackle* (rough finishes), gray or brown *hammertone* (smooth finishes with mottled color effects) and bare metal (only in aluminum). Steel chassis bases are normally available in the wrinkle finishes or with zinc plating. Upon special order, other finishes can be supplied, usually at increased cost.

The type of sheet metal finish to be employed by the builder depends upon his own individual preference. As far as this author is concerned, however, the rough finishes are least desirable because of the difficulty in cleaning dust from the surface.



STANDARD METAL GAUGES

GAUGE NO.	AMERICAN OR B.& S. [1]	U.S. STANDARD [2]
10	.10190	.140625
11	.09074	.125000
12	.08081	.109375
13	.07196	.093750
14	.06408	.078125
15	.05707	.070312
16	.05082	.062500
17	.04526	.056250
18	.04030	.050000
19	.03589	.043750
20	.03196	.037500

[1] USED FOR ALUMINUM, COPPER, BRASS, AND NON-FERROUS SHEETS, WIRE, AND RODS.

[2] USED FOR IRON, STEEL, NICKEL, AND FERROUS ALLOY SHEETS, WIRE, AND RODS.

Fig. 1 Standard metal gauge chart showing thickness of materials in thousandths of an inch.

Metal Gauges

In the selection of sheet metal components from parts catalogs, the prospective purchaser may be somewhat misled by the indicated *gauges,* as the thickness gauges of aluminum and steel are determined by different standards. Figure 1 gives the actual thickness of both materials in relation to their gauges. Because of the relative softness of aluminum, it is often advisable to employ a thicker gauge for a given project than would be used if steel were employed.

Standard Relay Rack Dimensions

Some years ago a uniform set of "standard rack dimensions" was defined. These are known as *Western Electric* dimensions, and were first used for telephone and commercial radio installations. They were soon adopted by amateur constructors for the mounting of equipment. Rack dimensions are based on the width and height of unit panels, plus standardization of the spacing of rack mounting holes and panel notches. Panel width is uniformly 19 inches, while the height is always a multiple of 1¾". The latter dimension is known as "one rack unit," and panels can be obtained from this size up to 21 inches (twelve rack units.)

Figure 2 illustrates the pattern of mounting hole and notch spacing. As can be seen at the left, the top panel mounting hole in the edge of the rack is located ¼" from the top of the rack. From there on down, the hole spacing measures alternately 1¼" and ½". Panel notches are always spaced so that they line up with the mounting holes. The centers of outside notches are usually located ¼" or 1½" from the edges, with other notches being spaced as uniformly as possible.

Although "W.E." rack dimensions have always been considered to be standard in the electronic industry, some variations have appeared from time to time. One of these termed *universal* or *amateur* rack mounting is similar to the "W.E." standard, except that additional mounting holes are drilled at the points indicated by *X* in Figure 2. This changes the hole

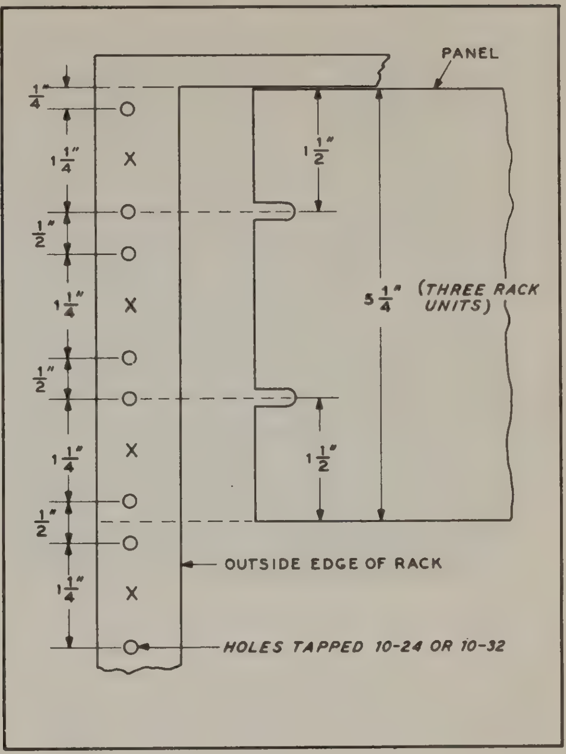


Fig. 2 Standardization of "relay rack" dimensions permits uniformity of electronic unit packages and allows mounting flexibility. Rack panels are multiples of 1¾ inches.

spacing sequence to ½″-⅝″-⅝″-½″, etc. The purpose of universal spacing is to permit the mounting of 19″ rack panels having other than "W.E." notch configuration.

Standard rack dimensions possess the advantage of permitting uniformity of electronic unit sizes, plus great flexibility in rack mounting of the equipment. Chassis bases used with standard rack panels are usually 17″ in length, and up to 13″ in depth. Standard racks are available either as fully enclosed cabinets or as simple channel iron frames. The vertical front edges are generally drilled and tapped to accept 10-32 or 10-24 machine screws. Overall rack heights may range all the way from 10½″ to over seven feet. An example of a commercial rack and panel assembly is illustrated in Figure 3. Note the spacing of mounting screw holes where one unit has been removed.

In past years, amateur constructors often built metal or wood frames to support rack units. Most, however, now prefer to purchase factory built racks. With the recent trend toward compact, table mounted equipment, the use of large rack supported assemblies by amateurs is losing popularity.

METALWARE FABRICATION

Such a large variety of prefabricated metalware is commercially available to the hobbyist that is rarely necessary or desirable for him to make his own sheet metal components. Home fabrication of large foundation units is not generally recommended, as such operations require considerable metal working knowledge, plus special machines and tools, such as a sheet metal *shear* (for cutting), a *brake* (for bending), and a *spot welder* (for

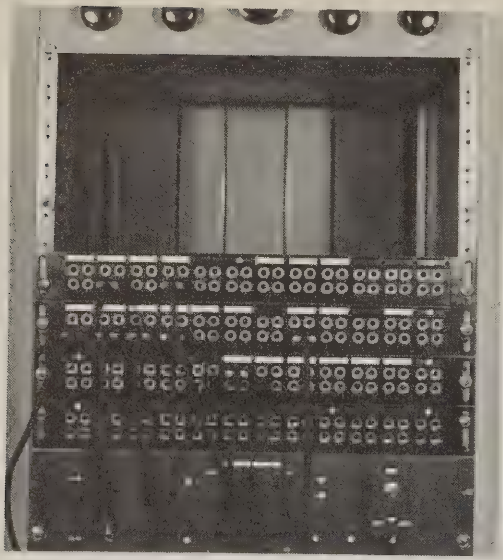


Fig. 3 This illustrates the method of mounting equipment in standard relay racks. Note spacing pattern of holes in front edges of rack.

assembly). It is not beyond the capability of the average electronics enthusiasts, however, to make small sheet metal parts such as brackets, panels, and small, open end chassis bases. No equipment, aside from ordinary home workshop tooling, is normally required. Aluminum is best for such work, and large sheets can be purchased at sheet metal shops or larger hardware stores.

Cutting Sheet Metal

Very thin metal can be cut with *tin snips.* This method is not suitable for the heavier gauges which are employed in the fabrication of electronic foundation components. The home builder can accurately cut and bend sheet aluminum up to 14-gauge in thickness, in the following manner:

1—Place two lengths of one inch angle iron in the bench vise. These pieces should be longer than the material to be formed.
2—Lay out lines on metal with scriber, indicating edges to be cut.
3—Insert sheet metal between angle irons, positioning scribed line flush with irons. Angle iron edges should also be flush with each other. Tighten vise jaws. (If extremely wide metal is being worked, it may be necessary to clamp ends of the angle irons with "C" clamps.)
4—Scribe sheet metal deeply on each side, along angle iron edges, as shown in Figure 4A.
5—Place hands on metal, close to cutting lines (Figure 4B). Bend to desired angle. To break, bend back and forth, about 30° each way, until metal fractures cleanly.
6—Remove work from vise and smooth edges with file.

Aluminum Recording Discs — Cheap Chassis Material!

An excellent source of material for fabrication of small parts can often be found at radio broadcast stations in the form of *used* aluminum base recording discs. The discs are made in diameters up to sixteen inches with a layer of acetate, and during the recording process a thin, continuous thread is cut from the plastic surface.

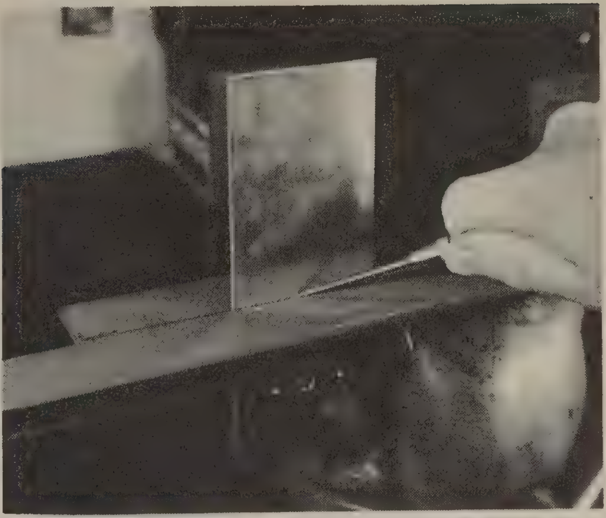


Fig. 4A Scribe sheet metal deeply on each side along edges of the iron.

Rectangular pieces of about 50 square inches can be cut from a 16 inch disc without running into the center hole, or up to 120 square inches if the presence of the hole is not objectionable.

During the process of making parts from recording discs it is suggested that the acetate coating be left on, as it will protect the aluminum base from fingerprints and scratching. All layout markings (which can be done with a scriber on the acetate surface) will be removed when the plastic is stripped from the metal. To remove the plastic, first place fabricated part in boiling water for one minute. Then, remove it from the water and chill immediately in cold water. Finally pull off acetate coating with pliers.

Drilling Holes in Metal

From a practical point of view, the greatest chore of electronic construction involves cutting holes of various sizes and shapes in the metal foundation. On the industrial production line this is accomplished by large punch-presses which may fabricate an entire chassis in one blow. In the home workshop, however, such openings must be made one at a time, generally with hand tools. The usual sequence is to employ twist drills for all holes

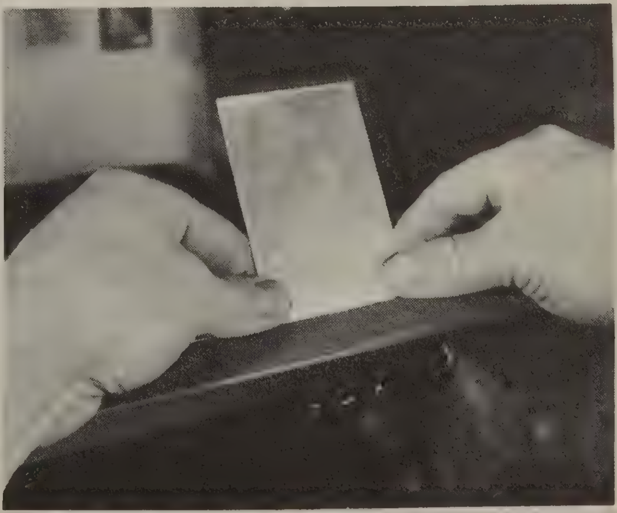


Fig. 4B To break, bend the metal back and forth until material fractures.

DRILL-SPEED TABLE

(*ALL SPEEDS IN R.P.M.*)

DRILL DIAMETER *INCHES*	ALUMINUM OR BRASS	MILD STEEL
1/16	9170	1833
1/8	4585	917
3/16	3056	611
1/4	2287	458
5/16	1830	367
3/8	1525	306
7/16	1307	262
1/2	1143	229
5/8	915	183
3/4	762	153
7/8	654	131
1	571	115

Fig. 5 Optimum spindle speed for different machine drill diameters.

up to a quarter or three-eighths of an inch in diameter. From there on, holes are enlarged by using other tools, such as the *tape reamer, circle cutter, circle saw,* or screw operated *sheet metal punch.*

Following are several drilling principles which should be helpful to hobbyists engaged in sheet metal fabrication:

1—Whenever possible, chuck speed of the drill should be adjusted in inverse proportion to twist drill diameter. In other words, as the drill size increases the speed in RPM's (revolutions per minute) should be decreased. The chart in Figure 5 indicated the optimum spindle speed for different drill diameters, in relation to materials being worked. Obviously it is impossible to maintain these figures when a single speed, portable electric drill is being employed. Where a drill press is concerned, however, chuck speed can be easily adjusted as will be discussed later.

2—Do not attempt to drill holes over ⅛″ in diameter in metal without first providing small "pilot" holes. As mentioned in Chapter II, only the angular edges of a twist drill point do any cutting; the tip does none. This can be observed in Figure 6A which shows that the absence of a clearance hole for the tip of the drill prevents the cutting edges from making contact with the work. In a case such as this a hole might eventually be "brute-forced" through the metal but such an operation would require excessive pressure on the drill point, and would doubtless result in an inaccurate job. By providing a clearance hole as illustrated in Figure 6B, large drills will cut metal easily without drifting off center.

From the foregoing, the builder should not conclude that it is necessary to go through many drilling operations in order to reach large hole diameters. Normally the original center punch indentation will serve as an adequate starting point for small drills, up to about ⅛″ in diameter. A hole of this size will then provide sufficient clearance for larger drills, up to ¼″, and so on, in a size ratio of approximately 2:1.

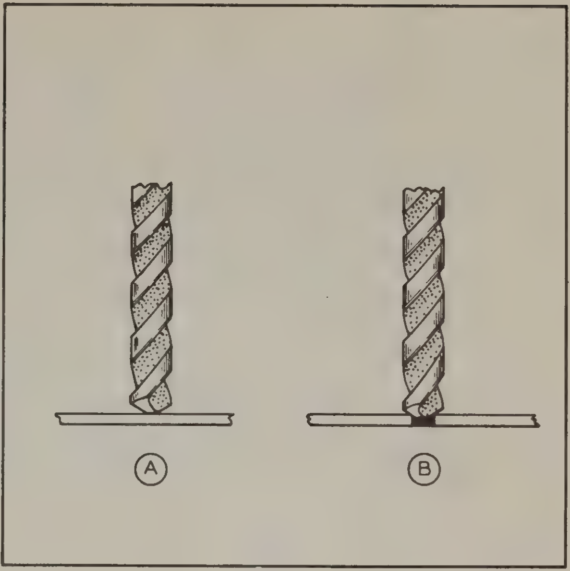


Fig. 6 By providing a tip clearance hole (right) cutting edges of the drill are allowed to contact the work. Absence of such a hole (left) makes it difficult to start the drill.

Machine Screw Drill Sizes

The chart in Figure 7 indicates the correct *numbered drill* sizes for machine screws and bolts which are most commonly employed in electronic construction work. Sizes for both screw clearance and thread cutting in metal are shown. In most cases it is advisable to use clearance drills one to two sizes larger than those indicated in the table in order to allow for slight inaccuracies in fit. A complete table of drill sizes can be found in the appendix.

Foundation Drilling

Before proceeding with foundation chassis drilling all suitable center points should be center punched as described in Chapter III. If layout paper has been employed, it is convenient to leave it in place throughout the drilling processes, as it will serve as a guide and will also protect the metal surfaces from damage. Before using socket punches, however, the builder should temporarily detach one edge of the paper from the sheet metal, and shake out all chips which have been entrapped. Failure to do this may result

MACHINE-SCREW DRILL SIZES

SCREW SIZE	DRILL TO CLEAR	DRILL TO TAP *
4/36	33	42
6/32	28	35
8/32	18	29
10/32	10	21
1/4-20	1/4"	6
5/16-18	5/16"	1/4"
3/8-16	3/8"	5/16"

* CORRECT FOR IRON, STEEL, BRASS, ALUMINUM. FOR TAPPING PLASTICS, INCREASE TAP-DRILL BY ONE NUMBER-SIZE, OR 1/64" IN THE CASE OF FRACTIONAL-SIZE DRILLS.

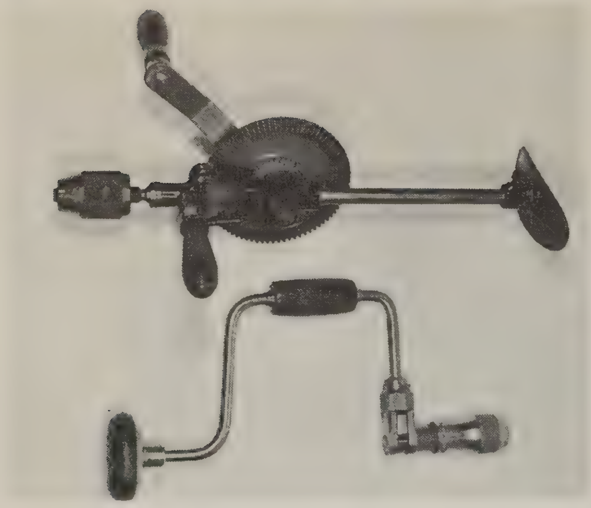


Fig. 8 Hand drill (top) is provided with a gear shift which allows two different spindle speeds. For heavy drilling and reaming the carpenter's brace (bottom) is very useful.

in surface scars caused by cuttings being pressed into the chassis surfaces by the punch die-edges.

The most efficient and foolproof drilling sequence is simply this: Drill *all* center punched points with the smallest twist drill called for (in no case larger than 1/8"). Then, enlarge holes as required, going from one size to the next larger. Follow layout directions carefully so as not to drill any holes oversize.

DRILLING TOOLS

Twist drills can be driven by hand operated devices or electric power. Illustrated in Figure 8 are two types of hand drills. The left one is a gear driven tool, having a three jaw chuck capable of accepting round shank twist drills. The model illustrated has a maximum shank capacity of 1/2", and is provided with a gear shifting arrangement which will permit two different spindle speeds. Hand drills of this type are also available in single speed models with 1/4" chucks.

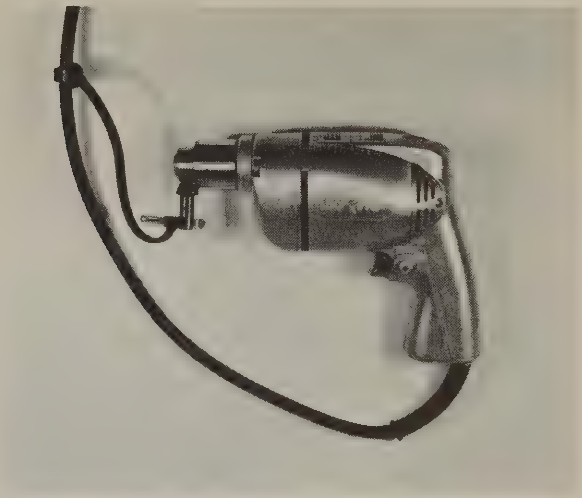
The *carpenter's brace*, also shown in Figure 8, is very useful for heavy work involving the drilling or reaming of large holes. Most braces are equipped with *square shank* chucks. Some will also handle round shank drills, but such a practice is not advisable in metal work. Insufficient speed of rotation for small drill bits and difficulty in clamping round shank drills securely in the chuck make for frayed tempers and poor workmanship.

Portable Electric Drills

There are so many inexpensive makes and models of portable electric drills available that the builder who can scape up the few extra dollars might better invest his money in such a tool in preference to the hand operated type. The savings in time and energy on the very first job will likely be convincing enough. In addition, it will be found that drilling of very small holes can be accomplished more accurately with less bit breakage and work damage when an electric drill is employed.

Portable electric drills are manufactured in a variety of sizes and styles. Probably the best type for general all-around work would be a medium duty tool with *Jacobs* 1/4" key-chuck similar to the unit illustrated in Figure 9. Light duty drills with hand tightened chucks are available at some-

Fig. 9 Slipping and scoring of drill shank which may occur with inexpensive hand tightened chuck can be minimized by employing drill having a Jacobs key chuck, shown on this typical light duty electric drill.



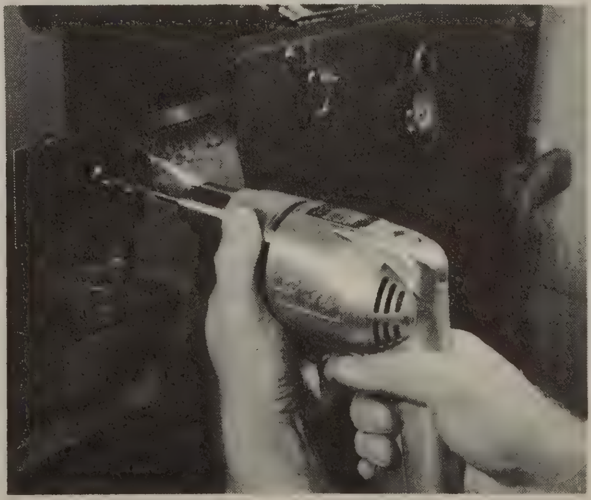
what less cost. Frequent drill shank slippage is likely to be encountered in such models however, and those with key-chucks are to be preferred. Most drills are equipped with "pistol" grips, as shown, although another type is obtainable which has a "hand-saw" grip. Choice of grip styles depends upon one's personal preference.

Electric Drill Operation

Whenever possible the material to be drilled should be clamped in a vise or secured by some other means. A quarter-inch electric drill should be held with two hands, as illustrated in Figure 10. (Be careful not to cover ventilating holes). In this manner it is possible to obtain good accuracy and to maintain better control over the tool. Although properly ground drill bits will normally require little pressure for cutting, there is often a tendency for larger drills to break through the work suddenly, and perhaps grab and twist abruptly. The "two hand" hold will reduce the possibility of damage to material and person. *Under no circumstances should small pieces of metal be held in the hand while being drilled with power tools.*

For very heavy metal work involving twist drills over three-eighths inch

Fig. 10 Hold the electric drill with two hands. You will have better control of the tool and will achieve better accuracy.



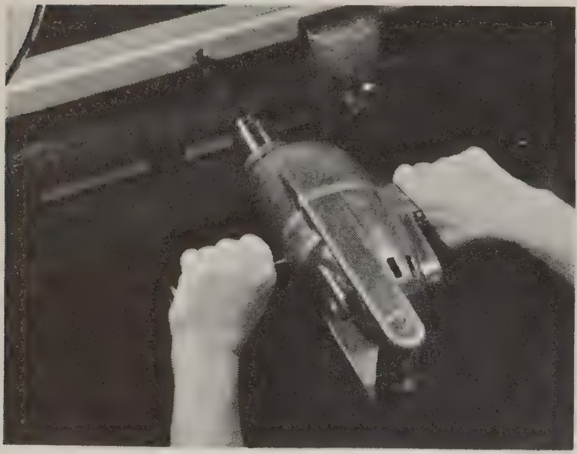


Fig. 11 Large electric drills have a great deal of power and should be held securely by means of the dual handles.

in diameter, larger portable tools such as the one illustrated in Figure 11 are often employed. The drill is provided with a pipe-like handle opposite the pistol grip. In operation, the tool should be held *securely* in the manner shown, as a drill of this size has a surprising amount of power and can easily tear itself from a loose grasp if the bit "grabs" in the work.

The Drill Press

Most builders do not have sufficient need for a drill press to warrant the purchase of such a tool. For some types of work, however, the drill press is decidedly advantageous and jobs which can best be handled in this manner are those involving large diameter twist drills, circle cutters and saws, and work requiring greater precision than can be obtained with hand held tools.

Drill presses are available as bench or floor mounted models, with the latter having the advantage of permitting greater work capacity between chuck and base. At the industrial level, drill presses are often equipped with tapered chucks which will accept only *taper shank drills.* As far as the hobbyist is concerned his typical drill press will have a *Jacobs* key-chuck with a maximum round shank capacity of ½″.

Calculation of Spindle Speed

The drill press permits change of spindle speeds in order to obtain the best relation between RPM's and drill diameters, as mentioned earlier. This is accomplished by means of step-type pulleys and *V-belt drive,* as illustrated in Figure 12. By using the following formula, these factors can be determined: (1) Drill chuck speed. (2) Pulley diameter-ratio necessary to produce a desired spindle speed. (All speeds are in revolutions per minute.)

$$\boxed{\frac{\text{SPINDLE SPEED}}{\text{MOTOR SPEED}} = \frac{\text{MOTOR PULLEY DIAMETER}}{\text{SPINDLE PULLEY DIAMETER}}}$$

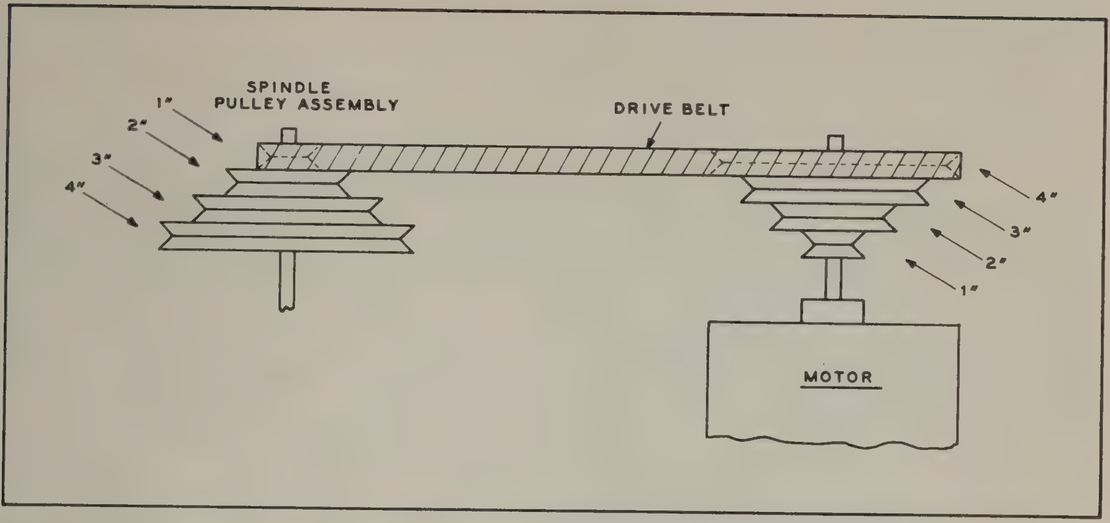


Fig. 12 "Step type" pulleys used on drill press motors and spindles permit rapid variation of spindle speed. The speed ratio is inversely proportional to pulley diameter ratio. When drive belt is in upper position, spindle speed is highest.

From the equation it can be seen that speed ratio is inversely proportional to pulley diameter ratio. For example, let us assume the following situation:

Motor Speed: 1800 RPM
Motor Pulley: 4″ diameter.
Spindle Pulley: 1″ diameter.
Spindle Speed: X

By substitution in the above equation and using simple cross-multiplication we can arrive at the unknown spindle speed, thus:

$$\frac{X}{1800} = \frac{4}{1}$$

$$X = 7200 \text{ RPM}$$

Double Speed-Change System

Chuck speed range can be extended by the use of an intermediate *idler pulley* as illustrated in Figure 13. This is especially advantageous for speed reduction jobs involving tools that require very slow rotation, such as the circle cutter. Calculation of spindle RPM's for the double speed change system can be best illustrated by means of Figure 13, which shows a typical drill press drive arrangement.

Safety First!

Probably the most important factors in the operation of a drill press involve personal safety. With this in mind, the following suggestions are offered:

1—When drilling holes of less than ¼″ diameter in medium or large sized foundation material, the work generally can be safely held on

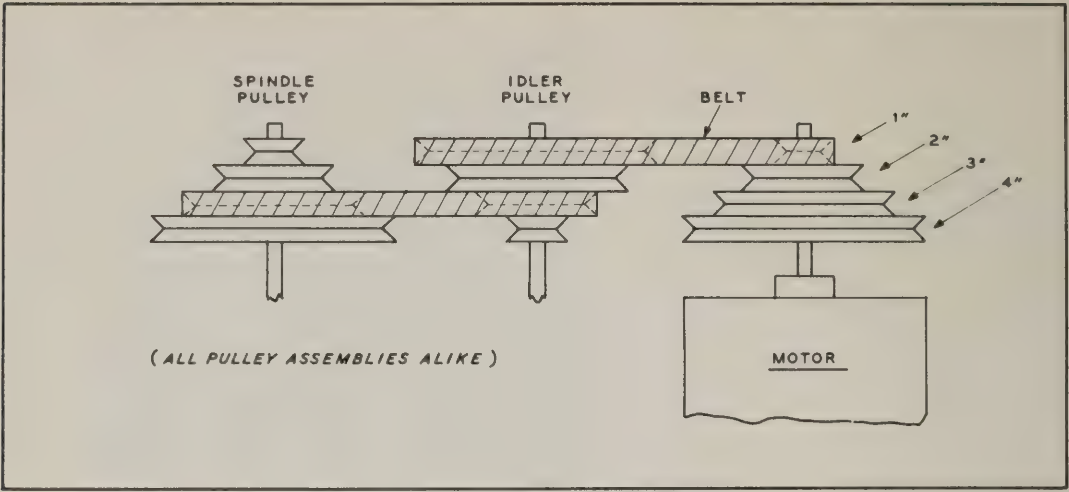


Fig. 13 A third "idler" pulley (between motor and spindle pulleys) permits extra wide range of spindle speeds. This is useful for very low speed applications.

the drill press table with one hand. The feed lever can be operated with the other hand. It may be convenient to let the sheet metal component rest against the drill press column in order to prevent rotation of the work.

2—In *all* chassis and panel drilling operations involving twist drills over ½″ in diameter, or circle cutters of any size, the work should be clamped to the drill press table with "C" clamps. A whirling sheet of metal can be a dangerous missile!

3—Small parts should never be held in the hand, but rather should be secured in a drill press vise, as illustrated in Figure 15.

4—Drill press motors should *always be stopped* while the work is being adjusted, especially when circle cutters are involved.

5—Do not operate any electric tools on the ground or on wet floors, unless the tool cases or frames are grounded.

6—Do not attempt to change position of belt drive while drill motor is running.

7—If drill press develops excessive vibration at high speed, reduce spindle speed by changing position of belt drive.

8—If flat metal parts are to be drilled place a scrap piece of lumber under the work so that the drill press table will not be penetrated.

Burring

Whenever holes are drilled through sheet metal, sharp *burrs* remain on the underside of the work. These should always be removed immediately as they can draw blood from the hands of the unwary builder. In addition, the presence of burrs may interfere with later assembly of parts.

The most satisfactory way of removing burrs from a small hole calls for the use of a twist drill somewhat larger than the hole involved. The burring drill can be rotated by hand, or it can be secured in a *hand chuck* as shown in Figure 16. Burring generally should not be done by a power tool, espe-

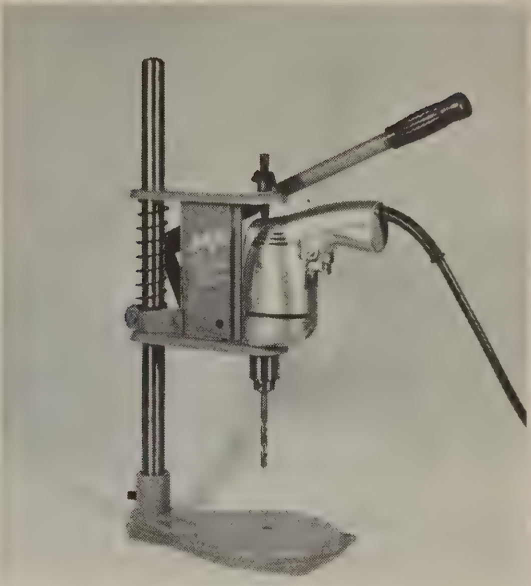


Fig. 14 When maximum accuracy is desired the portable electric drill may be clamped in an inexpensive metal stand, converting unit into home made drill press.

cially in soft aluminum as the drill is liable to take an excessive bite out of the metal. Where light metal is involved, burrs on large holes or cutouts can be eliminated with a file or a dull jackknife.

Enlarging Drilled Holes

The average home workshop electric drill has a maximum chuck capacity of 1/4″ but larger drill bits occasionally can be handled by utilizing *turned down shank* styles, an example of which was illustrated in Figure 1 of Chapter II. Where medium or heavy-duty electric tools are used, twist drills up to 3/8″ in diameter can be used for light chassis and panel work, working steel up to a maximum thickness of 1/16″, or aluminum up to 1/8″.

Enlargement of drilled holes can be handled by filing, or employing larger drill bits in a carpenter's brace or drill press. One very satisfactory method is to use a taper reamer (Figure 17). The tool shown has a square shank and tapers uniformly from 3/8″ to 1″ in diameter over its cutting length of 4½″. A gradual taper such as this is best for hole enlarging work. Some

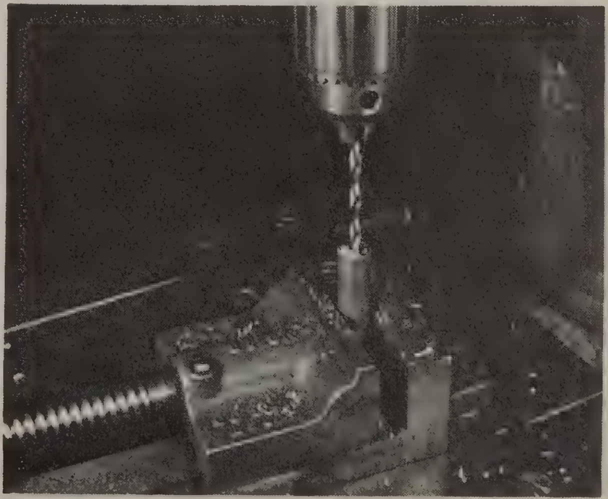


Fig. 15 Small parts should never be held in the hand while being drilled by power. Use a drill press vise.

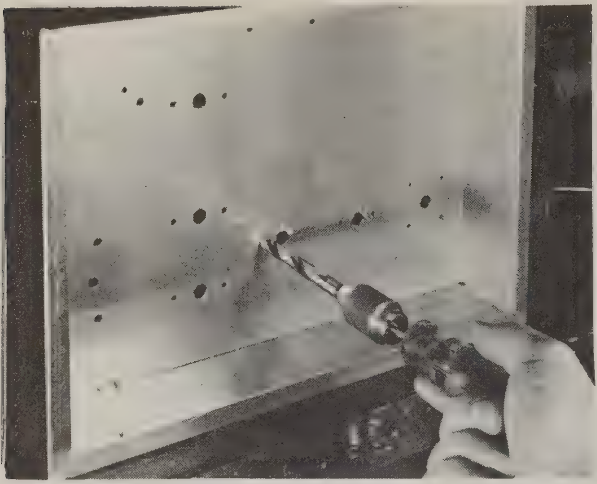


Fig. 16 Large burring drills may be held in the hand. Smaller ones are best secured in a hand-operated chuck. This tool is made by cutting off an old screwdriver blade two inches above the handle. Shaft is then threaded to fit hand drill chuck.

types of reamers having very wide taper angles and commonly known as *burring reamers* are designed for plumbing use and are not recommended for electronic metalwork.

Although the initial cost of the taper reamer is higher than that of a large twist drill, the former is advantageous from several standpoints: The reamer fills the hole size gap between the maximum capacity of the portable electric drill and the minimum socket punch size. It also permits the cutting of any odd-size hole within its taper range. In addition, holes can be enlarged more neatly and accurately with less expenditure of time and labor than is possible by using a file.

Operation of the taper reamer can be readily observed in Figure 17. The first step is to drill a hole of sufficient size to admit the small end of the reamer. Cutting is achieved by rotating the tool clockwise, while exerting only light thrust toward the work. If rotation becomes difficult as hole size increases the job can be facilitated by reaming alternately from one side of the sheet metal then from the other until the desired hole size is reached.

Socket Punches

The builder can best accomplish fabrication of chassis holes for tube sockets and the like, by employing *socket punches* (Figure 18). In order

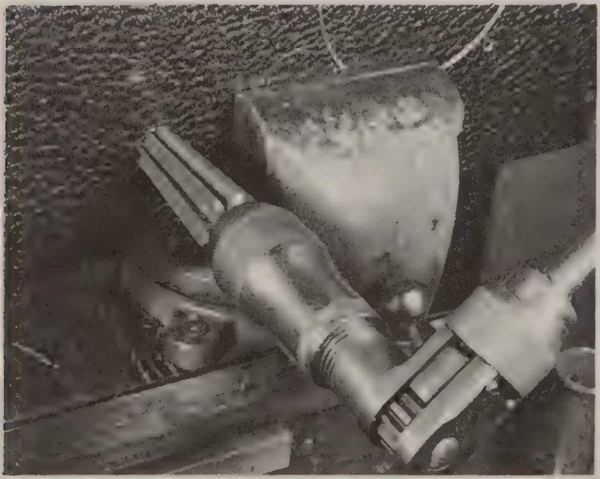
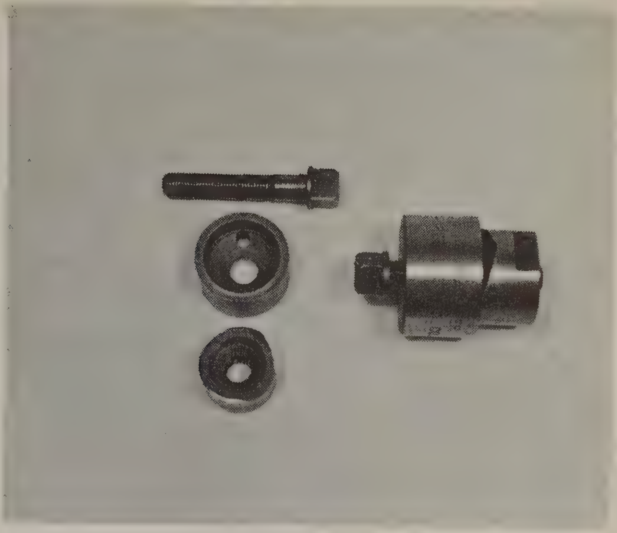


Fig. 17 Taper reamer is a very useful tool to enlarge holes up to about one inch in diameter.

Fig. 18 Individual socket punch parts are shown at left. Top to bottom, they are: takeup screw, die and punch. Note the small slug ejection hole in the die. Assembled punch shown at right.



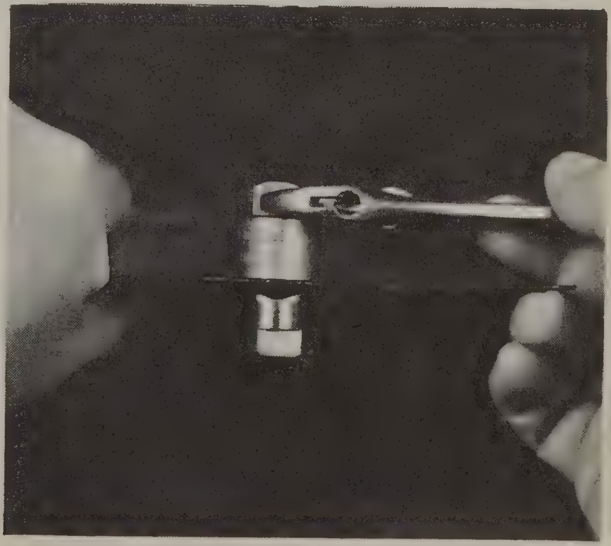
to start the tool in the material a clearance hole for the screw is drilled in the work. The punch is then assembled, with the die on one side of the metal and the punch on the other as shown in Figure 19. Rotation of the screw with a wrench provides the several tons of pressure needed to force the punch through the metal.

Punch Types and Sizes

Round, radio-type chassis punches are available in sizes from ½″ to over 2½″ in diameter. Square punches can also be purchased up to 1″ square. In addition to these, special types of punches are obtainable, such as the *D* and *keyed* styles (cutout shapes illustrated in Figure 20). The former is used for punching holes for components such as the *Amphenol type 78* miniature retainer ring socket and receptacle. The larger *Amphenol type S* retainer ring tube socket can be mounted in the keyed hole. In each case the special design prevents rotation of the component in its mounting hole.

For general construction the most frequently used hole punch sizes are ⅝″ round (for standard 7-pin miniature tube sockets and 83-1-R coaxial

Fig. 19 Turning takeup screw with a wrench exerts several tons pressure on the cutting edge. This action forces the punch through the sheet metal and into the die.



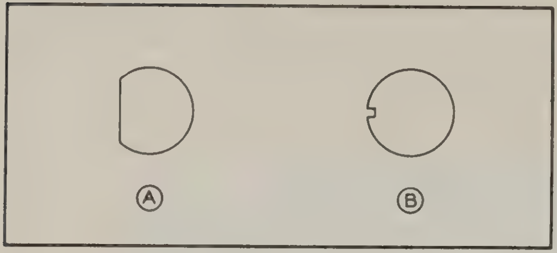
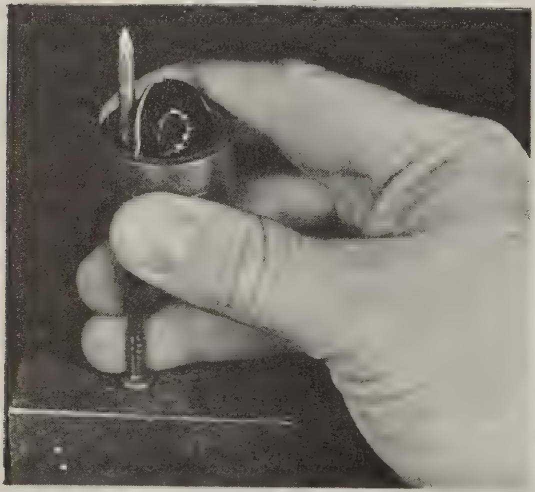
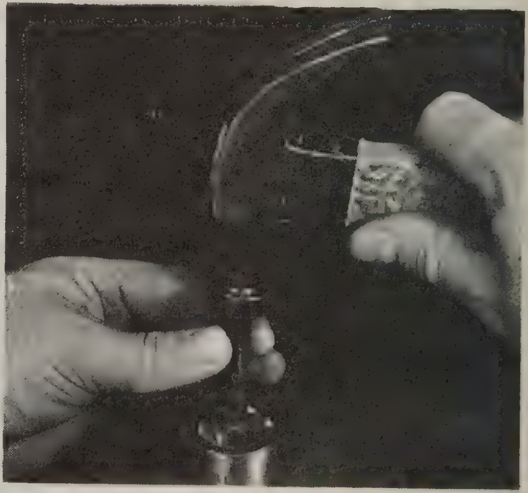


Fig. 20 Special metal punches cut "D" and "keyed" holes for sockets and receptacles.

connectors), ¾″ round (for 9-pin miniature tube sockets), 1″ round (for small octal sockets and twist-prong filter capacitor mounting plates), and 1 11/64″ round (for standard and retainer ring sockets and receptacles, and large twist-prong capacitors).

Using Your Socket Punch

Because of extreme tool pressures exerted during sheet metal punching the take-up screw threads must be lubricated with grease or heavy oil. A bit of lubrication should also be applied to the underside of the screw head. No lubrication of cutting edges is necessary, although the entire punch should be wiped occasionally with a slightly oily cloth to prevent rusting. Punches should always be assembled before storing in the tool box in order to protect cutting edges.

Figs. 21-23 The slug cut-out may be removed from the cutter with a nail, by striking the dissembled takeup screw with a hammer or by striking screw head on hard surface.

Newcomers to electronic construction work often find it difficult to remove the sheet metal slug which remains in the die after each punching operation. Slugs should never be pried out with a screwdriver, as this may damage the cutting edge of the die or the screwdriver blade. Some socket punches have, in addition to the takeup screw hole, a second smaller opening drilled through the die. This can be seen in Figure 18. This is to facilitate slug removal with the aid of a large nail or other suitable tool inserted through the small hole in die.

In cases where no ejection hole has been provided in the punch die, slugs can be removed by disassembling the punch and placing the die on the work bench with cutting side up. Place *head* of takeup screw on center of a sheet metal plate, as indicated in Figure 22 and strike the other end of screw *squarely* with a hammer. This action will force center of slug down into the depression in the die, thereby "shrinking" the diameter of the metal disc and permitting easy removal. (Takeup screws have sufficient end-bevel to prevent damage to threads by this operation.)

Slugs from smaller punches, like the ½″ and ⅝″ sizes, which have no ejection holes, can be cleared by loosening the screw until the punch can be removed, and then striking the screw head on a hard surface, as shown in Figure 23. This will knock out the slug, unless the clearance hole in the sheet metal has been drilled oversize.

CIRCLE CUTTERS

A versatile but potentially hazardous tool for cutting circular holes is the *fly cutter* or *circle cutter.* Shown in Figure 24, the cutter consists of a heavy vertical shank, through which passes an adjustable, horizontal arm. The actual *cutting bit* is clamped at the end of the arm and a twist drill held in the shank serves as a *center pilot.* The arm is movable, thus permitting the cutting blade to be positioned at the desired radius.

In addition to round shank styles, circle cutters can be obtained with square shanks for use in the carpenter's brace. For metal working, however, the only really satisfactory method of employing the circle cutter is in a slow speed drill press. A typical cutting operation should proceed as follows:

1—Determine location of hole center from layout. Center punch this point and drill a ⅛″ pilot hole.

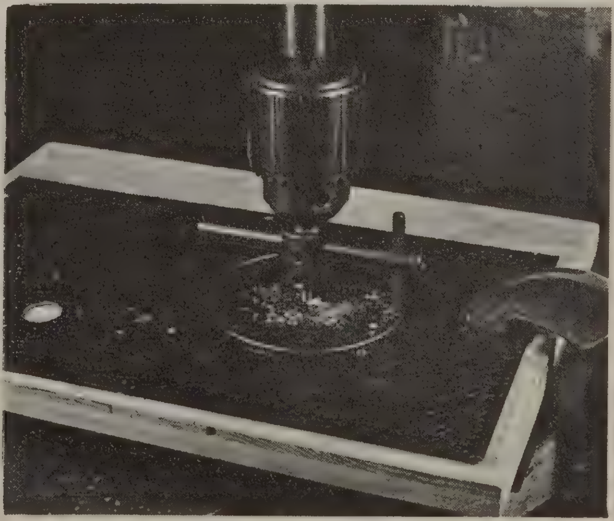


Fig. 24 The "fly" circle cutter is very useful for cutting holes one to five inches diameter. Work should always be clamped down and cutter operated at slow speed. Drill press is best for circle cutting.

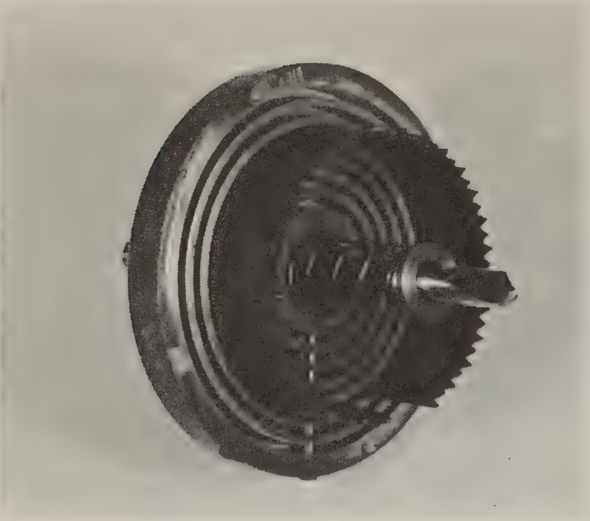


Fig. 25 This "hole saw" will cut seven different hole sizes by placing the proper blade in one of the grooves. The spring in the center of the unit serves as a slug ejector.

2—Cut a piece of scrap wood to about the same size as sheet metal work and clamp to drill press table.
3—Set drill press belt drive for slowest possible spindle speed.
4—Adjust circle cutter bit to desired radius. Securely tighten drill chuck and all set screws in cutter.
5—Take a light cut in the wood. Stop motor and check diameter of cut.
6—Position sheet metal part on board so that pilot drill is aligned to pilot hole in work. Clamp metal and wood support securely to drill press table.
7—Feed cutter slowly into sheet metal. Lubricate cutter blade freely with machine oil. Do not force blade into work as it may break, or gouge sheet-metal.
CAUTION: Do not place hands near rotating circle cutter. Always clamp work; never attempt to hold sheet metal with hands!

The Hole Saw

Illustrated in Figure 25 is the *circle saw* or *hole saw*. This tool is not quite as versatile as the circle cutter, in that the selection of hole diameters is limited to the available blade sizes. Most hole saws are supplied with seven different blades and will make cutouts from 1″ to 2½″ in diameter, in steps of ¼″. For portable electric drill work the circle saw is superior to the circle cutter, as contact between blade and work is made around the entire circumference instead of at just one point. In addition, the hole saw can tolerate higher speeds of revolution.

Whenever possible, hole saws (especially the larger sizes) should be used in a drill press, and for such work the suggestions outlined for the circle cutter also apply.

Circle Cutting By Hand

Two methods can be employed by the constructor to cut large, round holes. In either case the work is begun by scribing a circle of the desired diameter directly on the metal with a *divider*. One technique involves the center punching and drilling of small, closely spaced holes, all the way around and just inside the scribed circle. Next, the spaces between the holes

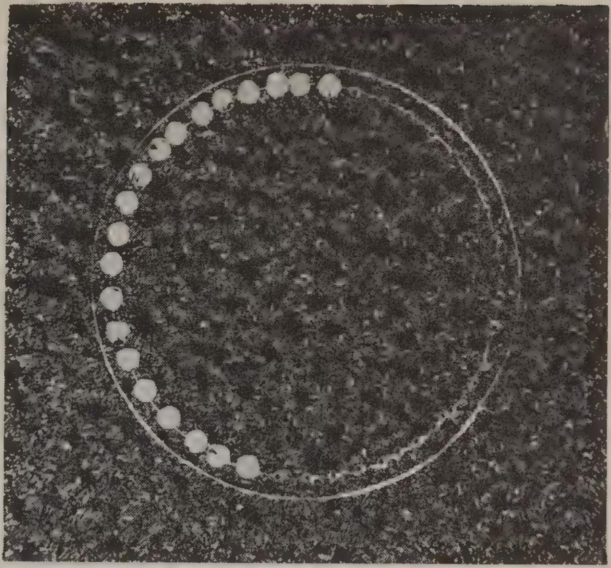


Fig. 26 One way to hand cut large circles is to drill small holes inside the circumference then cut out remaining spaces with coping saw.

are cut away with a coping saw. Finally, the inside of the large hole is smoothed up with a half-round file (Figure 26).

In the second technique only one starting hole is drilled inside the marked circle. A coping blade is then inserted through the hole, secured to the saw frame, and the entire hole is sawed out. For such work, special coping saw blades, having spirally cut teeth are very useful as they will saw in any direction without changing the position of the frame. The operator needs only to apply slight pressure in the desired cutting direction. Figure 27 shows a greatly enlarged section of a spiral toothed coping saw blade.

Experience has indicated that the multiple hole method is superior when thick metals are involved, such as encountered in rack panels. The second system is less time consuming when cutting thin chassis stock. In both instances, holes and saw cuts should be kept well inside the circumference of the scribed circle.

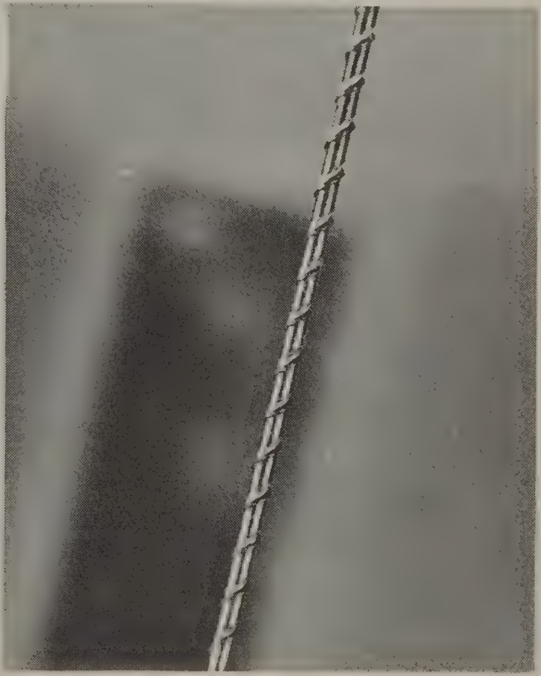


Fig. 27 This magnified view shows the "spiral tooth" coping saw blade. This blade will cut in any desired direction without changing position of the frame.

Cutting Rectangular Holes

Square corner openings can be made by employing a square sheet metal punch and punching all the way around the perimeter. This system entails a good many drilling-and-punching operations, and a more efficient method is to punch out only the four corners, then complete the job with a *keyhole hacksaw* and flat file.

Openings with square corners can also be fabricated by drilling holes of ⅜″ to ½″ diameter inside the four corners of the proposed cutout. The balance of the job is again accomplished with saw and file. The first step is to lay out locations of saw starting holes inside the four corners, as described earlier. Prick-punch the four corners of the proposed opening, and center punch drilling points for starting holes or takeup screw holes. Next, scribe straight lines between prick punch marks to indicate outside edges of cutout (Figure 28A). Drill the four starting holes well inside of scriber marks. Finally, if a square punch is to be used, punch out all four corners, aligning punch edges squarely with scribed lines. Or, if hacksaw starting holes have been provided, file each corner square, as illustrated in Figure 28B. This will facilitate starting of your saw blade. In either case, complete the cutout by sawing just inside scribed lines, using keyhole hacksaw (fine-toothed blade). Clean up edges of completed cutout with fine-cut, flat file.

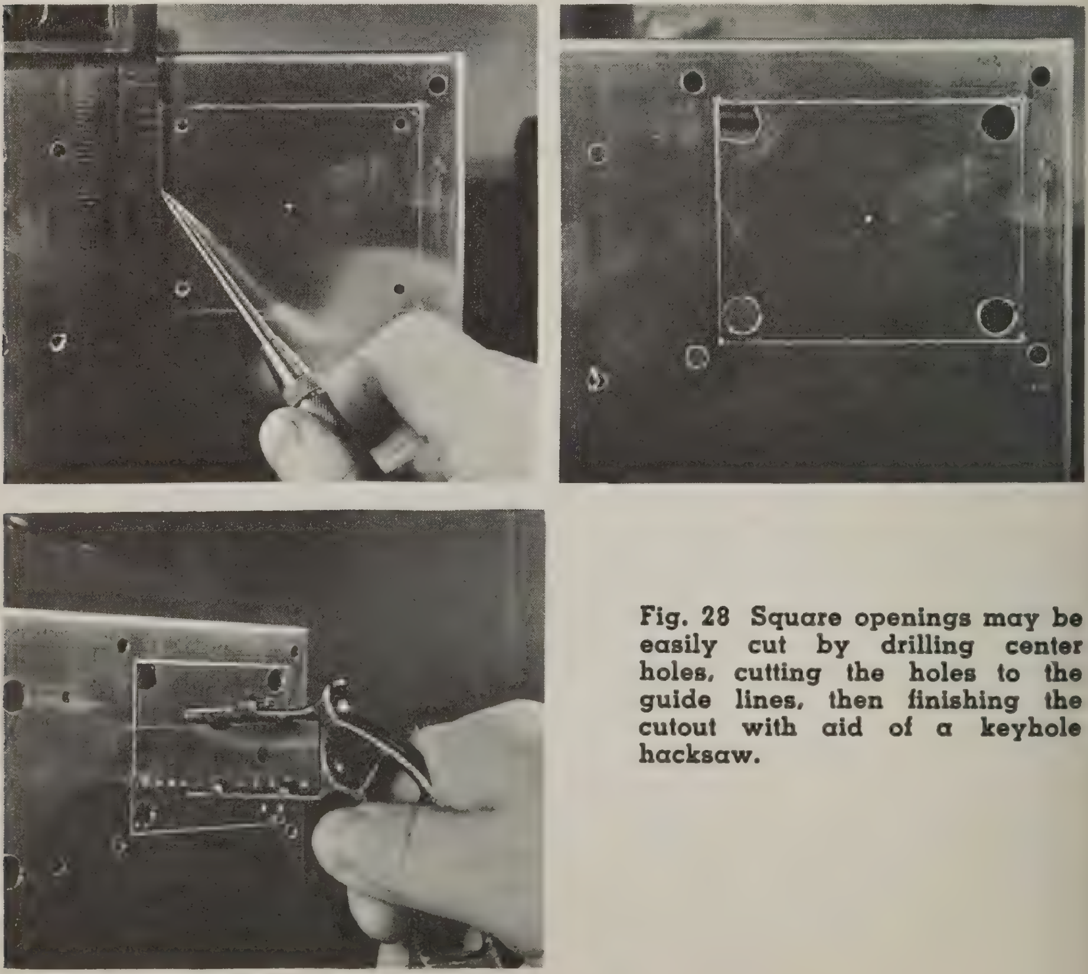


Fig. 28 Square openings may be easily cut by drilling center holes, cutting the holes to the guide lines, then finishing the cutout with aid of a keyhole hacksaw.

CHAPTER V

Partitions, Shielding, and Ideas

Rarely is it necessary to provide shielding of any kind for audio frequency equipment. Where r.f. units are involved, however, sheet metal partitions are often required between stages in order to prevent feedback and instability. In addition, the problem of *TVI* (television interference) has made the over-all shielding of such equipment practically imperative.

Each electronic construction project presents its own shielding problem, and it is obviously impossible to cover all the possible variations in this publication. Instead, a few general principles will be discussed which are applicable to practically all equipment designs.

Mounting Partitions

Shielding partitions can be mounted in two different ways. A simple method is to bend right angle lips at the bottom edges of the sheet metal. The lips and chassis are drilled and the partitions are then secured in place with machine screws, lockwashers, and nuts, as shown in Figure 1.

A second method makes use of *spade bolts.* As shown in Figure 2 the spade ends are fastened to the bottom edges of the partition with machine screws and nuts. The threaded ends of the spade bolts are inserted through holes in the chassis and secured with lockwashers and nuts.

Lip mounting is best for flat, unbent partitions, as it is possible to obtain better rigidity and to maintain a right angle with chassis. *Spade bolt mounting* is most suitable for bent partitions, as it is difficult for the constructor to fabricate sheet metal components which will have both vertical and horizontal angles.

Over-all Shielding

When complete "r.f. tight" shielding of an electronic unit is required, it is best to employ perforated sheet metal to provide adequate ventilation. Suitable material for such work is obtainable at hardware stores and hobby shops in the form of "do-it-yourself" aluminum.

Inasmuch as TVI suppression is a prime consideration in r.f. equipment it is very important that the edges of all shielding panels make good electrical contact to prevent leakage. Continuous contact can be obtained by using right angle aluminum corner stock, by employing bare metal throughout, and by spacing mounting screws not more than two inches apart. Figure 3 illustrates a cutaway section of a typical shielding enclosure. Fabrication of such an enclosure can be handled in the following general manner:

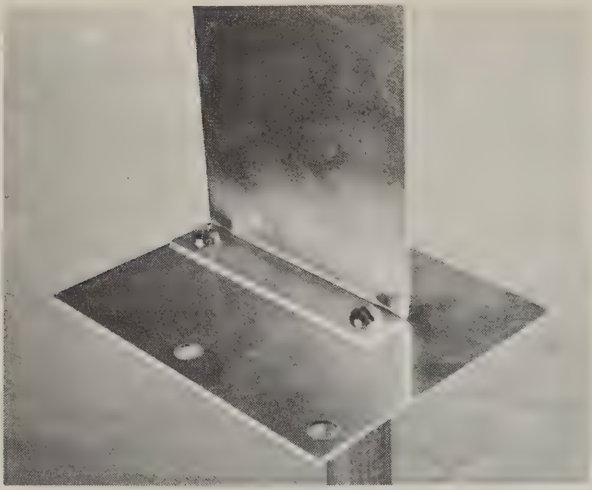


Fig. 1 A flat shield partition may be mounted by bending a right angle lip at the bottom then drilling and attaching it with small hardware.

1—Carefully determine dimensions required for shielding panels, allowing for metal thickness, when necessary. Mark sheet metal accordingly, using scriber and combination square. (If you make the inside dimensions of the enclosure equal to the outside dimensions of the chassis top, it is possible to overlap the chassis edges and secure the two together without using corner angles at these points.)
2—Cut shield panels to size. (Superior results can be obtained if this job is done on a sheet metal shear.)
3—Cut angle stock to suitable lengths.
4—Lay out and drill mounting screw holes in edges of panels, only. (These should be several number-sizes larger than required for screw clearance, to allow for some adjustment in final assembly.)
5—Temporarily assemble sheet metal panels and corners to chassis using "C" clamps. When proper fit has been obtained, mark all drilling points on corner angles by scribing through holes in shielding panels.
6—Before disassembly, place a small piece of masking tape on each part and mark with suitable identification. This will make later reassembly less difficult.
7—Drill and burr all holes in corner stock. Tap holes as required for mounting screw threads. Parts are now ready for final assembly.

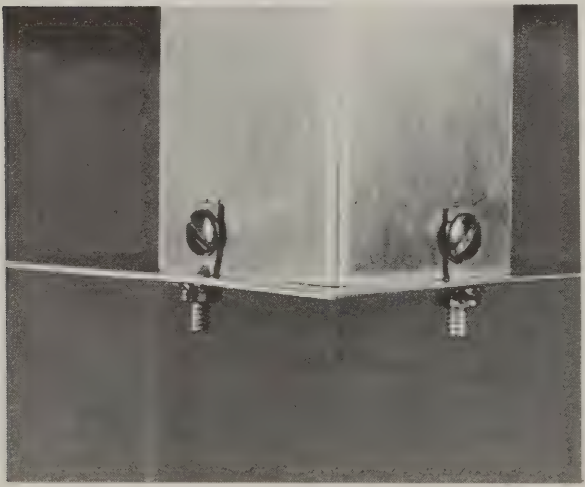


Fig. 2 Angular partitions are best mounted by using "spade bolts."

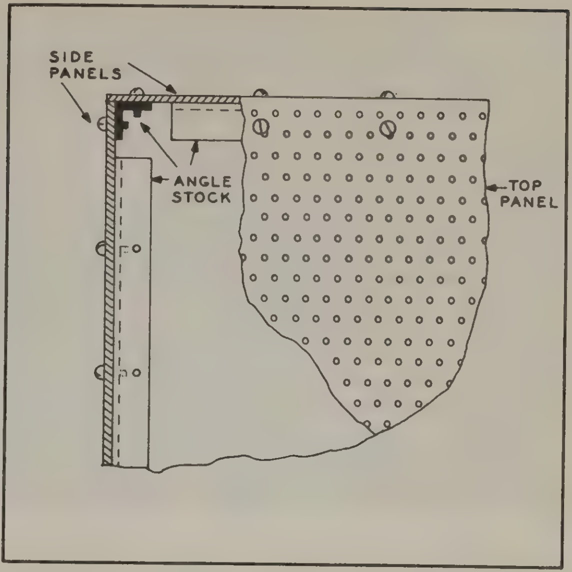


Fig. 3 Shown is a cutaway corner section of a shielded enclosure. The use of angle stock at the corners, bare metal at the joints and close spaced screws reduces leakage of r.f. power to a minimum. Small perforations in the metal shield provide adequate ventilation but do not impare quality of the "r.f.-tight" enclosure.

Finger Stock

Because of the necessity of drilling numerous mounting holes, it is frequently undesirable to employ angle stock between shielding enclosures and the front panels of electronic units. In such cases it is possible to secure electrical contact between the two surfaces by employing *contact finger stock*. This material is available from electronic supply houses and is made specifically for such applications. Finger stock comes in long, continuous strips which can be cut to suitable lengths, drilled, and secured to the edges of shielding panels with machine screws, as illustrated in Figure 4. The fingers should protrude slightly beyond the shielding panel edges so that they will make pressure contact with the back side of the front panel. The rear of the panel should be clean of paint at the points of contact.

REPAIRING ERRORS IN SHEET METAL

No matter how much care the hobbyist exercises in his construction work, occasional errors are bound to creep in. The metalworking flaws most

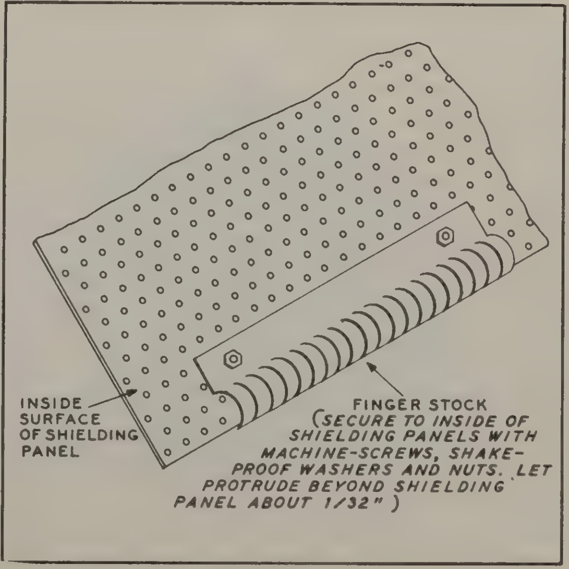

INSIDE SURFACE OF SHIELDING PANEL
FINGER STOCK (SECURE TO INSIDE OF SHIELDING PANELS WITH MACHINE-SCREWS, SHAKE-PROOF WASHERS AND NUTS. LET PROTRUDE BEYOND SHIELDING PANEL ABOUT 1/32")

Fig. 4 "Finger stock" secured to edges of door panel will provide good electrical contact with enclosure. This material may also be used for "r.f.-tight" joint between enclosure and front panel, eliminating necessity for drilling many unsightly holes in panel for angle stock.

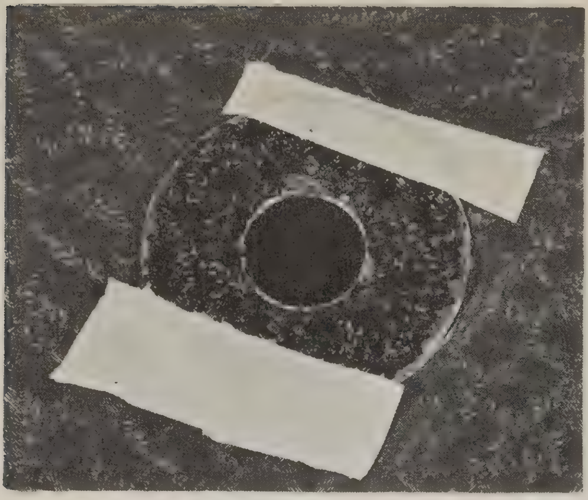


Fig. 5 Undersize socket holes may be accurately punched to larger diameter by taping original "slug" back into the hole. Takeup screw clearance is then centered for new punching job.

difficult to correct are holes which are too large in size. Generally, however, repairs are possible and should be attempted, as sheet metal components are expensive and represent a lot of hard work on your part.

Enlarging Punched Holes

It is not difficult to enlarge a punched hole. The problem of centering over-size punches on previously cut holes can be solved in two ways:

1—Flatten out the slug previously cut (or punch a new one from scrap metal) and use it as a filler, securing it into the hole with masking tape (Figure 5). Proceed with the punching of the larger hole as usual, enlarging the pilot hole in the filler slug if necessary.

2—A simple centering method is applicable if coordinate center-lines are still visible on metal or layout paper. Close inspection of a socket punch die may disclose four fine marks engraved 90° apart around the circumference and at the cutting edge. By aligning these marks to the respective center lines on the work, the punch will be accurately positioned for use (Figure 6).

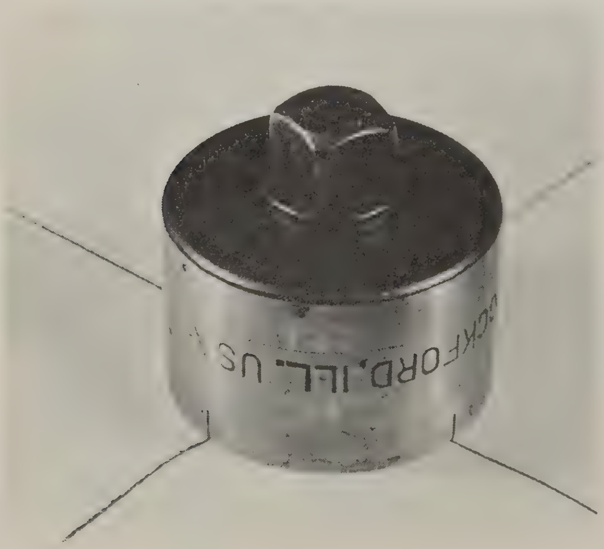


Fig. 6 Ninety degree index marks on punch die permit alignment of punch with layout center lines as shown.

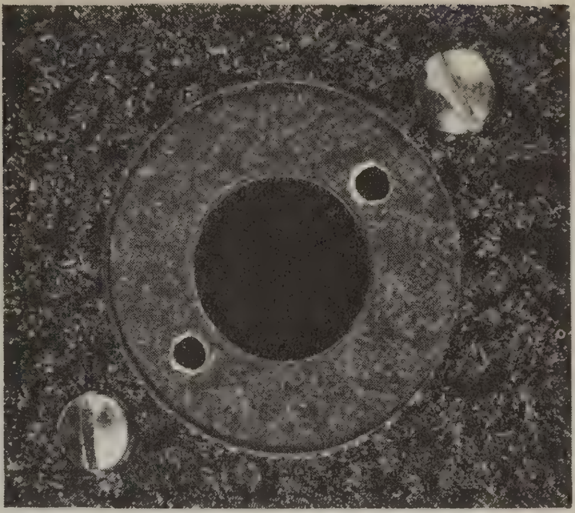


Fig. 7 Chassis hole may be "shrunk" by cutting correct size hole in scrap of sheet metal which is secured to underside of chassis.

"Shrinking" Punched Holes

The best "hole shrinking" solution, outside of starting over, is to cut a new hole of correct size in another piece of sheet metal. This plate can then be secured to the underside of the chassis with hardware, as illustrated in Figure 7.

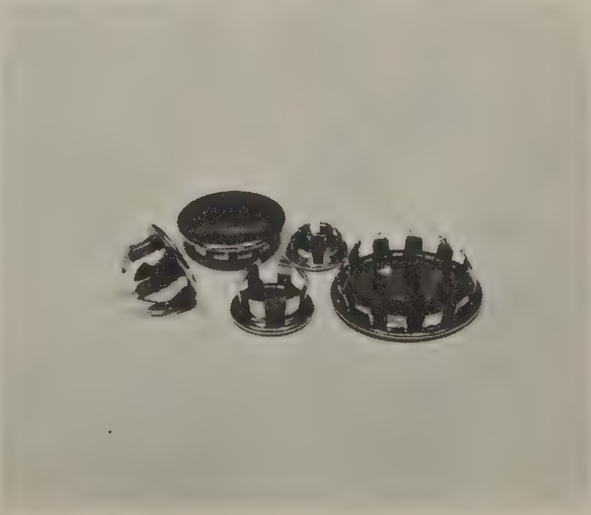
Small, screw size holes which have been mislocated can be filled by simply inserting a machine screw and securing it with a nut. In work which involves bare sheet steel which is to be subsequently painted, small holes can be closed by soldering and the surface is then filed smooth. Aluminum is difficult to solder so this method is not suitable with that material.

Filling Large Holes

Snap hole plugs, (Figure 8) are designed specifically for the purpose of covering undesirable openings in sheet metal. These are available in several diameters from ¼″ to 1″, and are usually finished in bright nickel plating. Hobbyists who desire to refinish snap hole plugs to match chassis colors can do so by first sanding off the plated surface, then painting to suit.

Oversize screw holes can be tolerated unless they are so large that the screw heads pass through the material. In this case the best solution is to use a large *flat washer* under the screw head and also under the mounting nut.

Fig. 8 "Snap plugs" available in several sizes may be used to fill extra chassis holes. Metal fingers hold plug firmly in place.



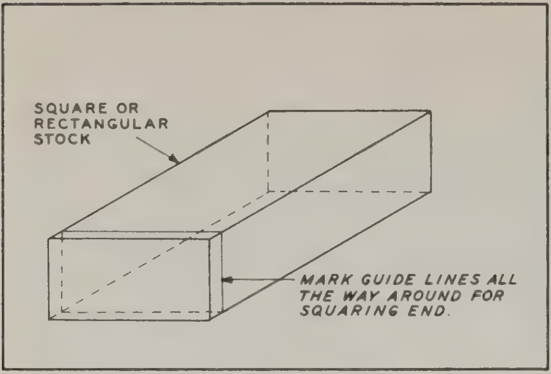

SQUARE OR RECTANGULAR STOCK
MARK GUIDE LINES ALL THE WAY AROUND FOR SQUARING END.

Fig. 9 Guide lines are marked on square stock to make rectangular cutoff in manner shown.

MISCELLANEOUS METAL WORKING

As the builder progresses further into construction work he is likely to encounter metal working problems involving materials other than sheet metal. The following are a few hints which should aid in the fabrication of small components from round or rectangular metal and plastic stock.

Two types of jobs which seem to be unusually difficult to accomplish with home workshop tools are the fabrication of square ends on round or rectangular stock, and the drilling of end holes in such stock in order that the holes start in the center and remain centered and coaxial.

Squaring Ends

If high precision is required, then the only satisfactory method for making cutoffs or squaring the ends of stock is to use a *metal turning lathe.* Few builders have access to such a machine however, and must look to other means. Square ends of good accuracy can be made on *rectangular stock* by laying out guide lines *completely around* the *stock* using a scriber and square, as indicated in Figure 9. The material is cut with a hack saw, keeping just outside guide lines, and the end is filed down to the guide lines.

The squaring of the end of *round stock* can be accomplished in the same manner, except for the marking. This is difficult to do with ordinary layout tools, and can be handled most accurately by scribing lightly with a *tubing cutoff tool* (Figure 10). The ends of short lengths of round stock having a

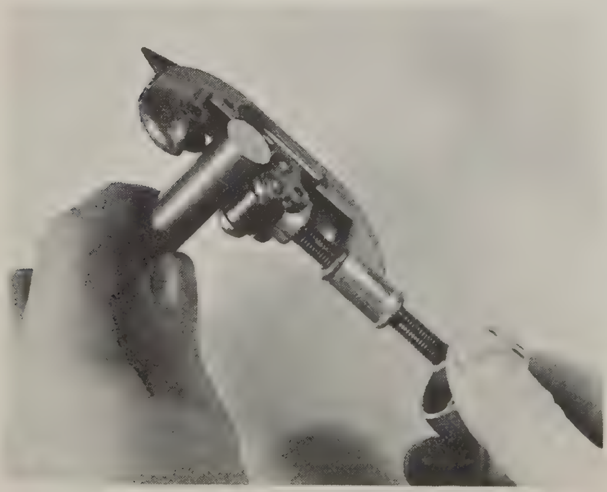


Fig. 10 Guide lines may be scribed accurately around circumference of round stock with tubing cutoff tool.

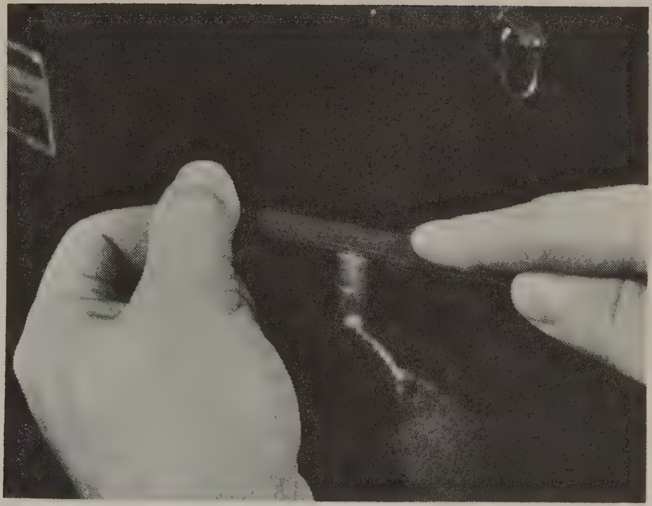


Fig. 11 Material may be squared with file. Hold tool with two hands so as to minimize "rocking."

diameter of ¼″ or less can be squared very accurately by securing in the chuck of an electric drill. The drill is clamped in a bench vise and a flat file is held against the end of the rod as it rotates.

A couple of generalizations can be applied to the end squaring of all materials, whether round or rectangular. If these suggestions are followed, good accuracy can be obtained:

1—When filing, cut only on forward stroke. Lift file from work on backstroke.

2—Support file with both hands, as illustrated in Figure 11. This will tend to minimize "rocking" of the file, which produces rounded ends on the stock.

3—Check squareness frequently during work, using combination square.

4—Clamp work in vise with minimum amount of protrusion. This will minimize "chattering" of stock when sawing or filing.

End Drilling of Metal and Plastic Stock

When machining round, hexagonal, or rectangular metal or plastic stock, the hobbyist frequently finds it necessary to drill holes in the end of the material. Important problems become immediately evident in such jobs. These are finding the center of the work, starting the drill on center, and keeping the drill centered and in line with the axis of the work.

Finding Centers on Round Stock

It is easy to locate the center at the end of a section of rectangular or hexagonal stock. All you need do is to scribe two diagonal lines between opposite corners. The point of intersection will be the desired center.

Location of centers on round stock can be accomplished most conveniently by using the combination square. If a *center head* is available for the square, the center of the stock can be found as shown in Figure 12. Rod centers can be located by employing the standard right angle head, as follows:

1—Set and lock combination square head so that 90° edge is at a point approximately equal to the radius of the work in question.

2—Position square at end of stock, as indicated in Figure 12 . Scribe a straight line across end of rod, in the manner shown.

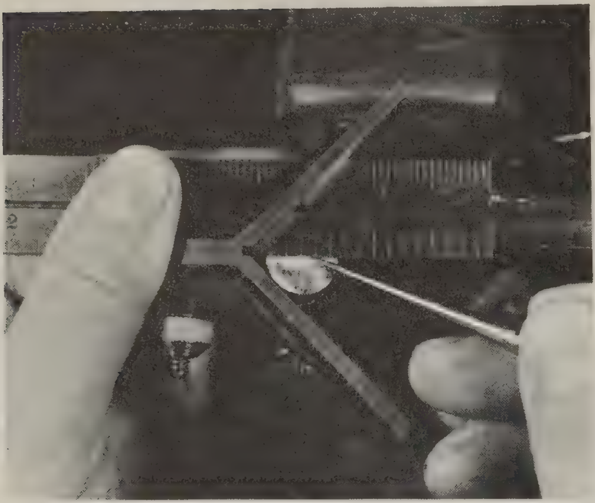


Fig. 12 By using center-locating head on combination square, centers of round stock may be accurately marked. Scribe two perpendicular lines which intersect at center, as shown.

3—Repeat this operation at 90°, 180° and 270° positions around work.

4—Center of work can now be located within the square formed by scriber-mark intersections (Figure 13).

Drilling Ends of Stock

If accuracy is a prime consideration, then it is mandatory that end drilling be done on a metal turning lathe. In such cases it is the usual practice to rotate the work in the *headstock chuck*, while the drill remains stationary in the *tailstock*.

The second best end drilling method involves the use of a drill press and drill press vise. Most drill press vises are provided with V-shaped notches, or removable "V" blocks, which serve to hold the work in a vertical position.

Before drilling, the center of the stock should be carefully marked with a center punch indentation. After clamping in the drill press vise, the work should be positioned so that the drill point will meet the punch mark without bending the drill shank; otherwise the hole will be drilled at an angle. For best accuracy, a small hole should be drilled first, then enlarged as required.

One difficulty which is often encountered in hand held drilling operations is the tendency for twist drills to drift off-center. Although this is not too serious in rough sheet metal work, it assumes considerable importance

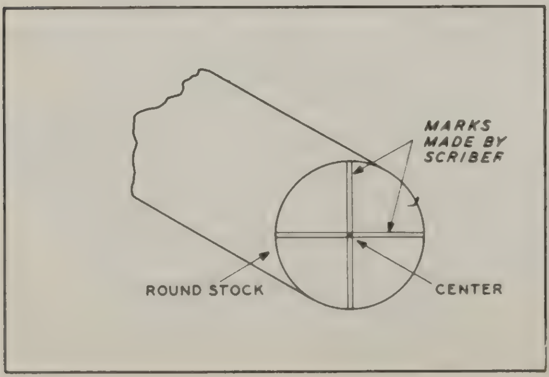


Fig. 13 Center of work is located within square formed by the scribed lines.

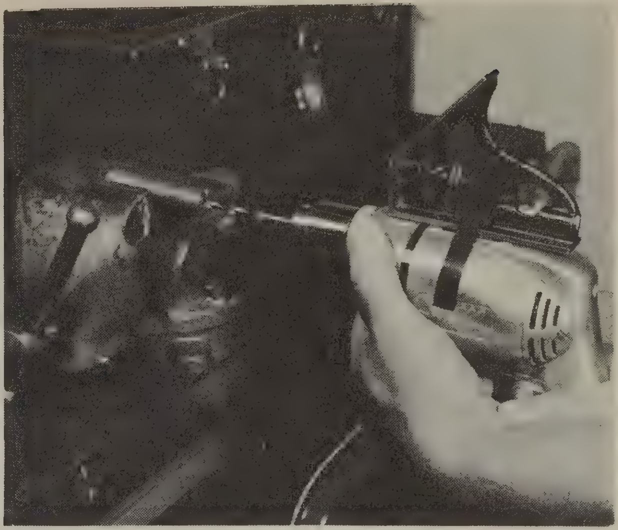


Fig. 14 Taping a spirit level to the top of your electric drill permits accurate alignment of the tool in both horizontal and vertical planes.

when small rods are being drilled. The trouble can be minimized by using sharp, accurately ground drills, and by drilling first with a small drill, employing light pressure, then enlarging the hole in small steps.

Another problem, prevalent in hand held deep drilling jobs, is the difficulty in maintaining the drill axis at right angles to the work. While the builder holds his drill in position he can generally align the tool by eye in the horizontal plane. He cannot, however, determine the accuracy of vertical alignment, and as a result the hole may be drilled at an angle. By first leveling the work in the bench vise, then taping a small level to the top of the drill (so that it is in line with the drill-axis) as illustrated in Figure 14, perpendicularity in both planes can be constantly checked.

THREAD CUTTING

During the course of project construction, the builder often comes across jobs which require cutting screw threads. Although some *external* thread cutting may be required at times, most jobs will involve *internal cutting* or *tapping*. For this work, externally threaded bits, called *taps*, are used, and these can be employed in hand operated *tap wrenches*. Two types of wrenches with taps in place, are shown in Figure 15. The "T"-handle style is suitable for most machine screw work up to size No. 10, while the other type, shown below, will afford additional leverage for larger taps.

Tapping: An Art, Not a Science

A hole must first be drilled before an internal thread can be cut in any material. The diameter of the hole is made equal to the minimum thread diameter of the tap. Figure 7, Chapter IV, lists the proper tap hole sizes for screws employed in electronic construction work. Although the hole tapping in sheet metal presents no particular problems, it should not be attempted if the metal is so thin that less than two or three threads can be cut. In extremely thin material it is better to use machine screws and nuts for component assembly.

Internal thread cutting in deep holes presents a few problems. Most machine-screw taps are manufactured with gently tapering points, which facilitate starting and progression into the work. As a result, full diameter threads

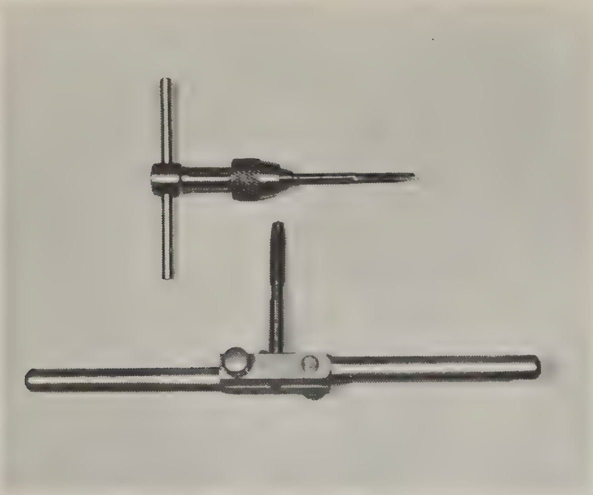


Fig. 15 Small "T-handle" tap wrench may be used with taps up to ¼-inch. Larger taps require heavy duty wrench. Standard thread cutting tap has a tapered end for easy starting. The "bottoming" tap has full diameter threads all the way to the tip.

cannot be cut all the way to the bottom of "partway" holes. Depth of such holes should be increased to allow for several unusuable threads at the bottom. If it is necessary to provide functional threads to the bottom of such holes, then special taps, known as *bottoming taps,* must be used. Figure 15 shows the shapes of both the standard and bottoming taps. As can be seen, the latter is provided with full diameter threads for nearly all its length. In actual practice, the standard tap should be used for most of the work with the other being employed for bottoming. If a bottoming tap cannot be purchased one can be made by grinding the tip from a standard one.

Thread cutting taps are made from hardened tool steel and, as they are quite brittle, will not tolerate much twisting or bending. Tap breakage is the most common trouble encountered in tapping operations, but can be minimized by careful handling. A typical tapping job should proceed in the following manner:

1—Clamp work in bench vise and drill and burr necessary holes in material.
2—With tap secured in wrench, insert tapered end in hole and rotate clockwise, exerting thrust only if necessary to start cutting action.
3—During cutting, the tap may bind frequently. When this occurs, back up a half turn to clear cuttings from flutes. A bit of machine oil in the hole will also facilitate rotation and cutting.
4—If very deep holes are involved, it is advisable to remove the tap a time or two and remove cuttings from hole. This is especially important when tapping aluminum and plastics as it is easy to strip the new threads in soft materials.

Removing Broken Taps

Happily for the builder, tap fractures usually occur outside of the hole rather than inside! This generally makes it possible to grasp the protruding broken tap end with a long nose pliers and to unscrew it from the hole. Removal can be made easier by placing a few drops of light oil on the tap.

Conversely, the removal of taps which have broken deep inside the work can be quite frustrating at times! Following are several plans of attack on this problem:

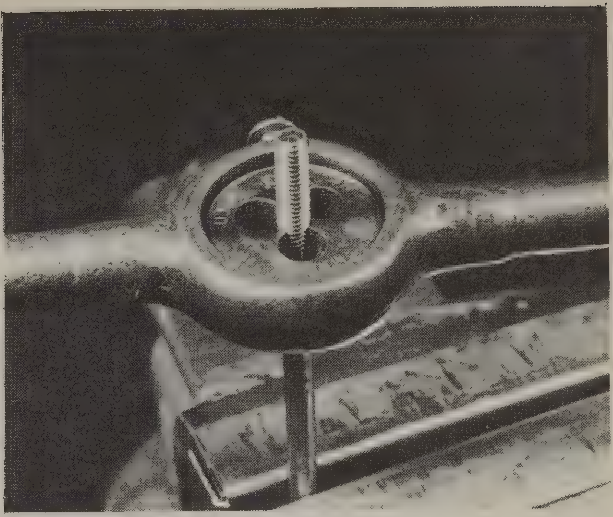


Fig. 16 Thread-cutting die is used for most electrical assembly work. Large diameter threads may sometimes be cut on a power lathe.

1—Obtain a *tap removing tool* from the hardware store. This tool is provided with long "fingers" which can be inserted into the hole, down alongside the flutes of the tap. The broken tap is then unscrewed from the hole.
2—Break up the tap by inserting a small, hardened pin-punch into the hole and striking the punch with a hammer. The pieces of tap can then be removed. If this operation damages the internal threads beyond repair, drill and tap the next larger size.
3—Soften the broken tap by bringing the work to a bright red heat, then allowing it to cool slowly. Drill tap out of hole. Drill and retap to larger size if necessary.
4—If the job is small and expendable, scrap it and start over!

External Thread Cutting

Whenever it is necessary to form threads on the outside of small, round stock, or to clean up damaged screw threads, the *thread cutting die* is used. Dies, like taps, are manufactured from hardened tool steel (Figure 16). In operation the die is employed in a hand operated wrench, known as a *die holder* or *die-stock*. Close inspection of the die will show that the thread cutting teeth taper outward toward one surface of the tool. This surface should always be presented to the work, and most dies have the instructions "start from this side" stamped thereon.

If external thread cutting is to be done, the diameter of the material should be approximately equal to the outside diameter of the desired threads. A die should not be called upon to "turn down" oversize material. "Backing up" the die is not ordinarily necessary, as is the case with tapping. However, if the openings around the teeth become filled with cuttings, they should be cleared out. External thread cutting can be facilitated by grinding a slight taper on the end of the work, by lubricating liberally with machine oil, and by starting the die so that it is square with the work.

MAKING VISE JAW COVERS

Most bench vises are equipped with hardened steel jaws, having serrated or milled surfaces. The serrations provide a better grip on heavy work than would be possible if smooth jaws were employed, but when soft metals and plastics are clamped between the jaws the materials are invariably imprinted with the cross-hatch pattern of the vise.

In order to eliminate scarring smooth *jaw covers* can be made which are placed over the regular steel jaws. The covers can be fabricated from thin lead, copper, soft steel, or aluminum. For most electronic work, copper is probably superior, as it is soft enough to prevent marring of the work, yet hard enough to resist damage to itself. The jaw covers can be fashioned from two pieces of sheet copper cut so that each will be one inch longer and one inch wider than the vise jaws. Fit the two pieces together and clamp into vise so that one inch protrudes above jaws, and one-half inch extends beyond each end of the jaws. Next, saw out the two rectangular notches in the upper corners of the material, as illustrated in Figure 17A, and clean up with a file. Spread the two jaw covers apart, and bend each down over the respective vise jaws (Figure 17B). Finally form fit the covers tightly to vise jaws by peening gently with hammer. The finished jaw covers will appear as in Figure 17C.

Using Your Electric Drill As a Lathe

It is possible to employ the portable electric drill for light duty lathe

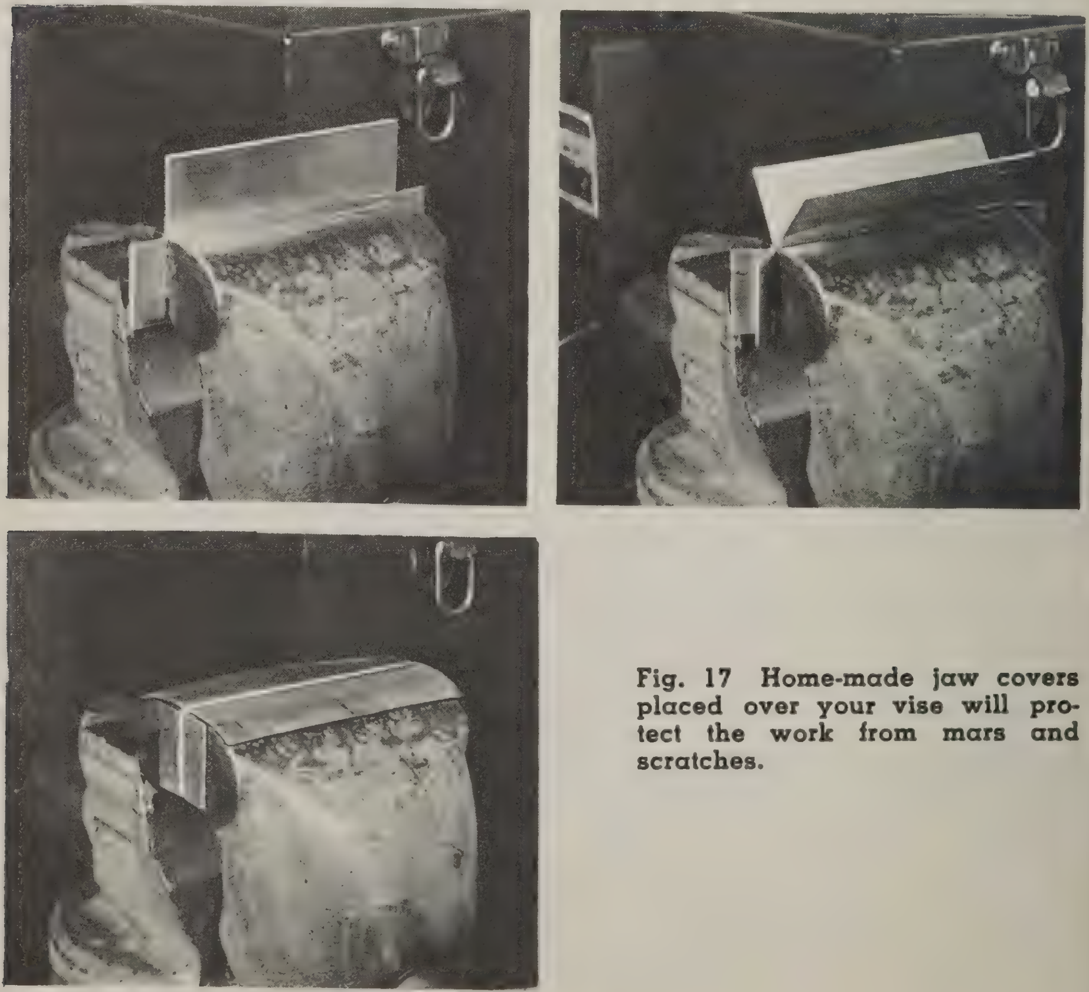


Fig. 17 Home-made jaw covers placed over your vise will protect the work from mars and scratches.

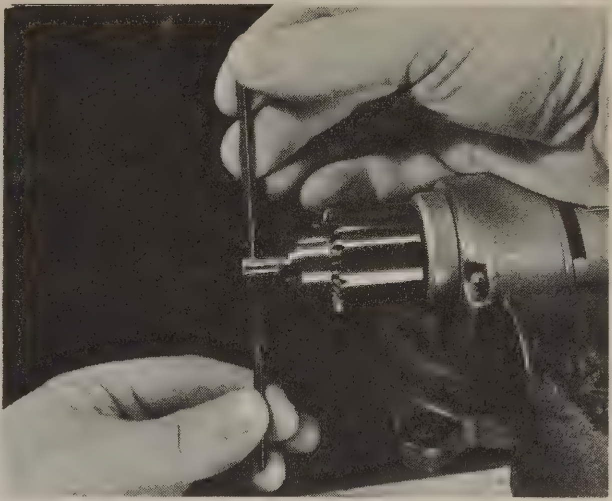


Fig. 18 Light lathe work such as filing, polishing and end squaring may be done by clamping portable electric drill in bench vise and chucking the work as shown. Length of work should be limited to about eight times its diameter. Large material should be handled in your drill press.

work, where short lengths of small round material are involved. Carefully clamp the drill in the bench vise and chuck the material, as illustrated in Figure 19. Various operations can then be done such as light file turning, polishing, and end squaring. In the case of filing, the cutting edges of the file teeth should always oppose the direction of chuck rotation. Whenever sandpaper or file are used, the abrasive should be moved frequently during turning operations, so that the "teeth" will not become clogged with cuttings.

Working Plastics

All plastic material employed in electronic equipment is formed by being molded under heat and pressure. Some materials become permanently solid during the molding process. These are known as *thermosetting plastics.* Included in this group are the *phenolics,* commonly known by such trade names as *Bakelite* and *Micarta.*

Other materials are referred to as *thermoplastics.* These solidify upon cooling after being molded. Unlike the thermosetting plastics however, the thermoplastics will soften or even melt upon reapplication of heat. Best known among the thermoplastics are *Polystyrene (Victron, Amphenol 912,* etc.), *(Lucite,* and *Plexiglass), Nylon,* and the cellulose base plastics *(Celluloid, Tenite,* etc.). Polystyrene materials have the best insulating properties at very high frequencies, but will soften at lower temperatures than others of this type.

Although the heating of thermosetting plastics caused by tool friction is of little concern, such is not the case with the thermoplastics. Drilling and cutting operations on the latter should be done carefully so that the tools will not become heated to the point where softening or melting of the work occurs. Generally speaking, machining should be accomplished at *high speeds* but with *slow rate of tool feed.* During drilling operations, chips should be kept constantly cleared from holes, in order to reduce friction and heating.

The tensile strength of plastics varies considerably, but in no case is it equal to that of the metals. Therefore, one should not expect plastics to withstand as much stress as metals. For example, threaded holes in most of the plastics have less holding power than their equivalent in steel, brass, or aluminum.

Cementing Plastics

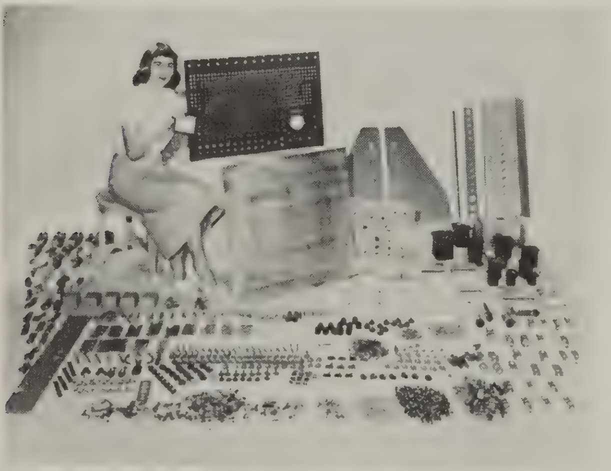
It is always important that the proper cement be employed whenever plastics are to be joined. Use of the wrong material will give poor results.

For polystyrene, use polystyrene cement, such as *Amphenol Polyweld 912*, or *Testor's Polystyrene Plastic Cement.* Suitable cements for acrylic materials, such as lucite and plexiglass are *General Cement No. 40* and *Amphenol Acryweld 901.* Special cements are also available for phenolic plastics, such as bakelite. One of these is *General Cement No. 32.* Whenever cellulose plastics, such as celluloid, are to be joined, use cellulose cement such as *General Cement No. 45, Testor's Household Cement* or *Duco Household Cement.*

DISPOSING OF CUTTINGS AND FILINGS

After each building session it is a good idea for the builder to make a practice of cleaning all filing and chips from the work bench and floor. There are practical advantages to this, in addition to the fact that it marks the constructor as a "good housekeeper." Metal chips and cuttings can be "murder" when pressed underfoot into wood, asphalt tile, and linoleum floors. Steel chips can even ruin the surfaces of concrete floors in time. Dust and metal filings which have found their way into potentiometers, or between variable capacitor plates can be the cause of noisy and erratic equipment operation.

Whenever steel work is being done, all electronic components which are equipped with permanent magnets should be covered or removed from the area. Included in this category are PM speakers and dynamic microphones. Just one single steel particle can impair the operation of such equipment.



Build your own computer from a kit! This "Heathkit" provides the proud assembler with a complete analog computer! Not a project for the beginner, this kit illustrates the complex field covered by kits, ranging from the one tube "Boy Scout" radio receiver to complex laboratory equipment such as shown here.

CHAPTER VI

Metal Finishing

Electronic chassis-hardware is available in a considerable variety of factory applied finishes. Even so, there are times when the builder may find it desirable or necessary to do his own metal finishing. Due to lack of knowledge or suitable equipment, such operations frequently produce less-than-satisfactory results. The information in this chapter will help to eliminate some of the difficulties so often encountered in this work.

In the electronic industry, sheet metal finishing is often accomplished by chemical means. At the hobby level, however, finishing is most likely to be done by applying "organic" materials, such as lacquer or enamel. The best sequence for such work is between the metal working and component assembly phases of project construction.

PAINTING SHEET METAL

The term "painting" covers a lot of territory, including the application of many types of finishes by brushing, rolling, dipping, and spraying. For metal finishing spraying generally produces the best results, and thus is most widely employed for such work.

Spraying Equipment

Hobbyists who do a great deal of metal finishing would do well to procure professional type spraying equipment. Minimum requirements for such an outfit include a motor driven *air compressor* and a *spray gun.* The compressor should be capable of delivering a steady flow of clean air at a pressure of 30 pounds or more per square inch (P.S.I.). The typical spray gun is equipped with a one quart paint container and may include several interchangeable nozzles for different spray patterns. In addition to the actual spraying equipment, the enthusiast who does a lot of metal finishing would be wise to provide some kind of well ventilated *spray booth.*

Most electronic builders do not have sufficient need for professional equipment to warrant the financial outlay which would be necessary. Therefore whenever large areas are to be finished it is generally more convenient and economical to obtain temporary use of the necessary gear from an equipment rental service.

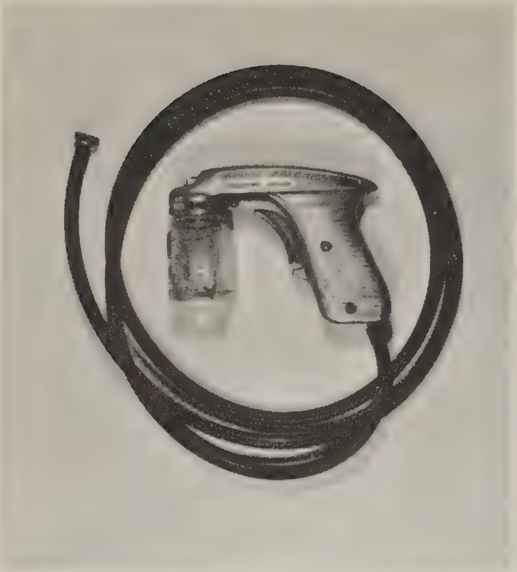


Fig. 1 Small paint spray gun such as shown here is suitable for touch up work and for painting small parts. Air pressure may be obtained from a spare tire or small compressor.

For light-duty spray painting, several small, rather inexpensive outfits are available. Figure 1 illustrates a small spray gun which is suitable for touchup work, or for finishing small components. Compressed air can be supplied by an automobile tire, and if the tire is inflated to about 40 pounds enough pressure will be available to spray more than the contents of the small one ounce glass jar. This quantity is sufficient to cover an area of two to four square feet, depending of course upon the type of finish being employed.

Another type of sprayer, which is not too expensive for home use, is shown in Figure 2. This style employs an electrically operated vibrator driven pump, and the container will hold about 24 ounces of liquid.

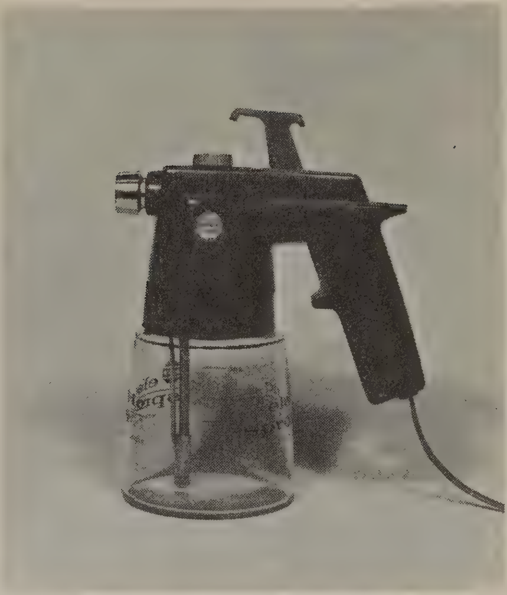
Pressurized Spray Gun

For convenient and inexpensive metal finishing, the pressurized *Aerosol spray can* (Figure 3) may be used. Many colors are available in both lacquer and enamel, and the pressure container can be purchased from hardware or automotive supply stores. Although the cost of the material contained in an Aerosol "bomb" is somewhat higher than the same amount of finish in the regular form, it is still the more economical form for occasional small jobs, as no other painting equipment is required. The spray can is also considerably cleaner, as no handling of finishes is necessary.

TYPES OF FINISHES

Many types of finishes are available for the hobbyist, and each one has certain interesting characteristics. There are a couple of generalizations which can be applied to practically all lacquers, enamels, and oil-base paints. Most of them are inflammable and should not be employed in any manner around open flames. In addition, the fumes of some materials are toxic when inhaled. Thus, adequate ventilation should be provided. In all cases it is wise to follow the directions for preparation and application as indicated on the container.

Fig. 2 The vibrator style paint sprayer requires no external air compressor or supply. The plastic container has sufficient capacity for large painting jobs.

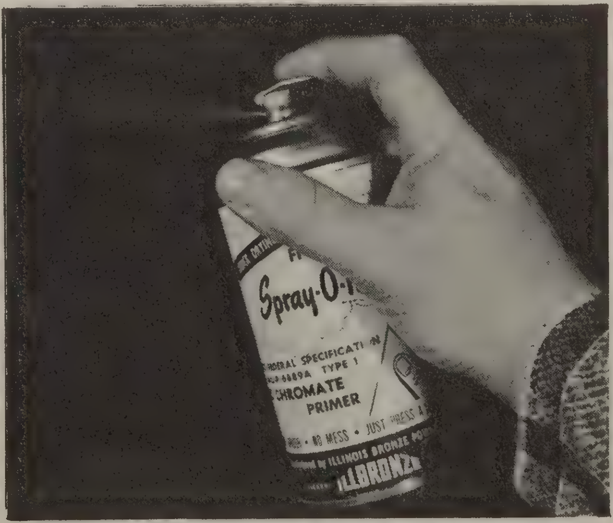


Enamels—Wood and Automotive

Enamels were once made exclusively from natural resins and plasticizers, suspended in hydrocarbon solvents. Most modern enamels now utilize man-made resins, and thus are generally termed *synthetics*. Although ordinary wood finishing enamels can be used on sheet metal components, the types produced for automotive finishes are better, as they dry faster and harder and with less dust pickup. Synthetic enamel coatings set dust-free within five to ten minutes, the actual drying time being dependent upon material, temperature, and humidity. When air-dried, however, such finishes may not harden enough for handling for several hours. Some enamels, principally the automotive types, can be dried more quickly by baking in an oven or under a heat lamp at a temperature of about 180°F. Baking should not be started until the material has set naturally.

Enamels have some disadvantages in the home workshop. Most of these are due to the average user's lack of suitable equipment for such work. Enamels are slower drying than lacquers; this results in more dust pickup before setting, unless the work is done in an exceptionally clean atmosphere. Enamel usually sets to a very high gloss, which makes dust flecks and other

Fig. 3 Many types and colors of finish are available in pressurized spray cans. These inexpensive units are very convenient for painting small jobs. Empty "Aerosol" cans should not be put in fireplace or incinerator as they may explode.



imperfections stand out. Such blemishes cannot be polished out of enamel, as is the case with lacquer. Finally, the mist which results from the spraying operation is heavy and may hang in the air for a considerable time unless good ventilation is available.

Lacquers

Lacquers are, for the most part, manufactured from cellulose nitrate or acetate, plus other resins and plasticizers contained in a suitable solvent. They may be pigmented (colored) or clear. Materials of this type in liquid form can be recognized easily by their pungent "banana-oil" odor.

The solvents used in lacquers are highly volatile and, as a result, most lacquer finishes set very quickly and can be handled in just a few minutes. This is advantageous for home metal finishing, as a coating will set before it has had a chance to collect appreciable dust. Lacquers generally dry to a dull or semi-gloss finish, often with a slight grainy or "orange-peel" effect. The final surface texture depends to a considerable extent upon the amount of thinner used in the mixture. Underthinning will usually give the dull, grainy finishes, due to rapid evaporation of the "vehicle." Slight overthinning, on the other hand, may produce a more glossy surface.

Lacquers are generally thinned more than enamels for spraying and, as a result, several successive coats of lacquer may be necessary to reach a suitable thickness. In order to obtain a "mirror finish" with lacquer, it is usually necessary to let the surface harden for several hours, then polish with an automotive *rubbing compound*. Most hobbyists, however, like the unpolished satin finish, and are inclined to leave it that way.

Lacquers exhibit some disadvantages, although none is of very great concern to the hobbyist. They generally cannot be applied satisfactorily with a brush because they dry rapidly. Some lacquers show considerable color change when exposed to sunlight. Lacquers cannot ordinarily be applied over existing coats of enamel or other paint. (A lacquer primer over bare metal forms the best base for a lacquer finish.) On the other hand, enamels can generally be applied over lacquer finishes. Lacquer coatings are not as flexible as enamel finishes, as a rule. Finally, due to rapid drying, it is sometimes difficult to achieve uniform coatings over large areas, especially if the lacquer is underthinned.

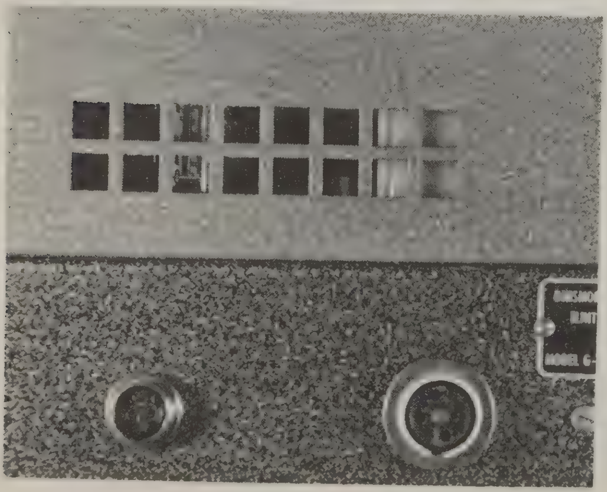


Fig. 4 Wrinkle (crackle) finish has been used on radio and electronic equipment for many years. This finish presents a neat appearance when new but is difficult to keep clean.

As far as the author is concerned, the lacquer finishes are generally superior to the enamels for casual finishing, as it is possible to achieve better and faster results with average home workshop facilities.

Wrinkle Finishes

A paint which has been employed on electronic and radio equipment for many years is known as *wrinkle* or *crackle finish*. This is still popular and in common use and is normally supplied in black or medium gray.

Wrinkle finishes (which are formulated from enamel bases) are applied in the same manner as the other finishes, except that heavier coats are frequently employed to achieve a satisfactory crackle. As the material dries, it expands somewhat, forcing the surface into a series of irregular "hills" and "valleys" which give it a rough texture. These finishes are available from electronic supply houses, and can be purchased in air drying or baking forms, with the baking type giving the most satisfactory results. Figure 4 illustrates the characteristic texture of the wrinkle finish. Crackle and wrinkle coatings are not too critical to apply, as the rough surfaces will hide imperfections to a greater degree than will the smooth finishes. On the other hand, it is considerably more difficult to remove dirt accumulations from the "valleys" of wrinkle finishes, especially if maintenance has been neglected for some time.

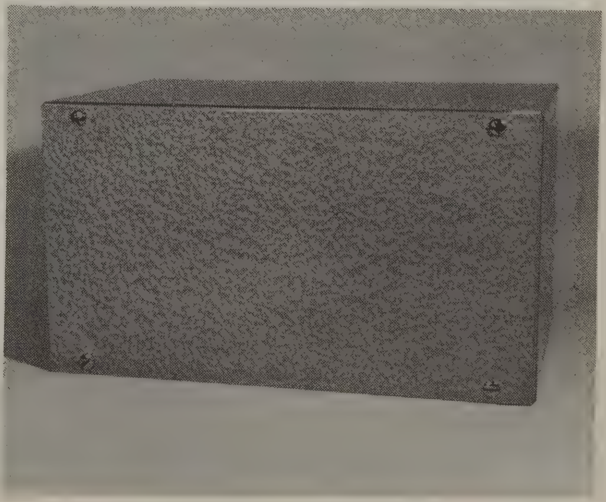
Hammertone

A recently developed finish, and one which has become very popular with metalware manufacturers, is called *hammertone*. It is so named because the color texture resembles that of a piece of hammered metal.

Hammertone finishes are usually composed of solid color enamels, to which have been added off-shade pigments which tend to resist mixing with the base material. When hammertone paint is applied to smooth surfaces the pigments separate and gather into little "islands" throughout the material. The result is a mottled color effect shown in Figure 5.

In addition to its pleasing appearance, the hammertone finish combines the advantages of both the rough and smooth solid color materials. The smooth surface of hammertone facilitates cleaning, while the mottled pattern tends to hide minor imperfections.

Fig. 5 Hammertone is a common finish used on inexpensive cabinets and boxes. The mottled effect is produced by irregular distribution of pigments in the enamel.

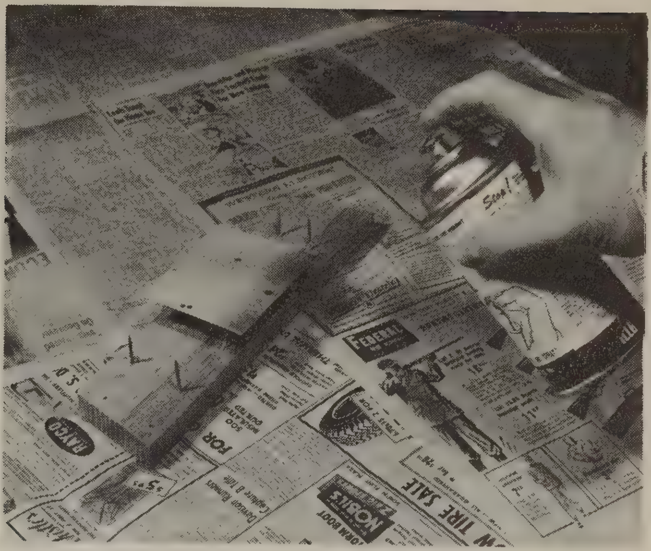


FINISHING SHEET METAL

Whenever electronic foundation-components are constructed from bare steel, it is imperative that the metal surfaces be protected in order to prevent rusting. As far as the amateur constructor is concerned, such components are nearly always finished by painting. Other methods, frequently employed in industry and usually involving plating with other metals, are too involved for the average home workshop facilities. Steel panels, chassis bases, and other components can be given enamel or lacquer finishes in this manner:

1. Complete all drilling, punching, reaming, and burring, so that the sheet metal components are ready for assembly.
2. Sand off all rust and old paint. Remove shine from glossy surfaces by sanding, so as to provide a better "tooth" for the finish. If an old finish is to be removed, the job can be facilitated by employing an electrically powered disc sander, obtainable from most rental services. Do not use excessively course grit as the metal may be scratched too deeply.
3. Brush dust from metal. Clean surfaces thoroughly with lacquer thinner or enamel thinner, depending on finish to be used.
4. Lay out overlapping sheets of newspaper where spraying is to be done, so that paint will not get on the surfaces. Choose an area which is well ventilated and as dust free as possible. Best results can be obtained if temperature is 70°F. or above.
5. Drive a few nails through a board. Lay board on newspapers with nail-points up. Place metal parts on top of nails, as shown in Figure 6. Do not place components directly on flat objects or on newspapers, as the paint will seep between the surfaces and cause blemishes and sticking.
6. Blow dust settlings from surface of metal just before spraying. Apply one or two coats of metal primer to one surface of metal. (Suitable primers are specified in manufacturers' instructions on finish containers.) A primer coat will adhere to bare metal much better than will a direct finish coat. Spray metal surfaces at an angle (Figure 6), keeping spray gun far enough from work (six to twelve inches, depending on type of gun) so that a smooth, even coat will result, and so that air or propellant bubbles will not form in the wet surface. Move sprayer constantly from side to side, at the same time working from top to bottom, until surface is evenly coated. Do not hold gun directly above work, as nozzle may drip on surface, causing a blemish in the final finish. If the job is "goofed," it is best to remove the finish, using rags and thinner—then start over.
7. After the primer has set, spray one or two finish coats in the same manner, again following the manufacturer's directions as to preparation and use of material.
8. Do not touch metal or do anything to raise dust until the finish has dried dust-free. When one surface has dried sufficiently, carefully turn work over and give other side the same treatment if desired. (It is a good idea to finish the front sides of panels, and the outer surfaces of cabinets *last.*)
9. After work is completed, thoroughly clean spray gun with thinner.

Fig. 6 Primer paint coat is applied with "Aerosol" spray.

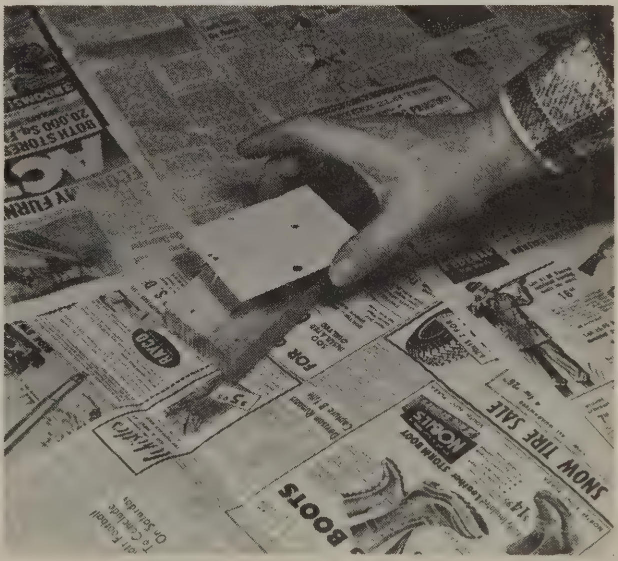


Handling Newly Finished Parts

Following are several generalizations on the handling of freshly painted sheet metal components:

1. If necessary to move work on which the finish has not set hard, grasp it at the edges, as shown in Figure 7, rather than on the surfaces.
2. Let lacquer finishes set several hours before polishing or assembling components.
3. Allow *one or two days* for air-drying enamel to harden before attempting to use. Even more time should be allowed for assemblies which have controls, panel bushings, and other components which exert considerable pressure on the finish surface.
4. Components with baked enamel coatings can frequently be assembled within an hour after the finish has cooled.
5. Do not apply wax to newly *enameled* surfaces for 30 days, as it requires a considerable time for all volatile elements to escape from these finishes. New *lacquer* finishes can be waxed within a week.

Fig. 7 After primer has set, apply one or two finish coats. Component is supported on nails driven into wood block.



FINISHING ALUMINUM

Although it is not ordinarily necessary to coat aluminum for protective purposes, it is a common practice on electronic assemblies to finish the outside surfaces for the sake of appearance. In amateur project construction this can be achieved by coating the material with lacquer or enamel. For industrial production aluminum is very often finished by a chemical process such as *anodizing*.

Etching Aluminum

Most manufactured unfinished aluminum parts are supplied with etched surfaces, rather than with mirror finishes. The satin-like texture of the etched aluminum presents a more pleasing appearance than a glossy surface and has less tendency to show blemishes and fingerprints.

Hobbyists desiring to duplicate a satin effect on home fabricated aluminum parts can do so by giving the metal surfaces a *caustic* etch, as follows:

1. Complete all cutting, drilling, and bending of aluminum components.
2. Make up etching solution by dissolving a small can of sodium hydroxide (ordinary household lye) in two or three gallons of lukewarm water. Solution is best contained in a concrete laundry tub or large crock (never in aluminum utensils, as the solution dissolves the metal). Stir with a stick of wood until solution clears. Avoid getting mixture on skin or clothes. (During the etching process an irritating gas is liberated; therefore, adequate ventilation should be provided.)
3. Place aluminum parts in solution so that all surfaces will be acted upon uniformly by the bath.
4. Frequently check progress of etching. When desired finish has been obtained, remove components from bath and wash them immediately with cold running water, wiping with a cloth, to remove the black deposit which has accumulated. (Figure 8 illustrates a piece from an aluminum recording disc. One half has been etched; the other half has the original mirror finish. Note blemishes on unetched portion.)

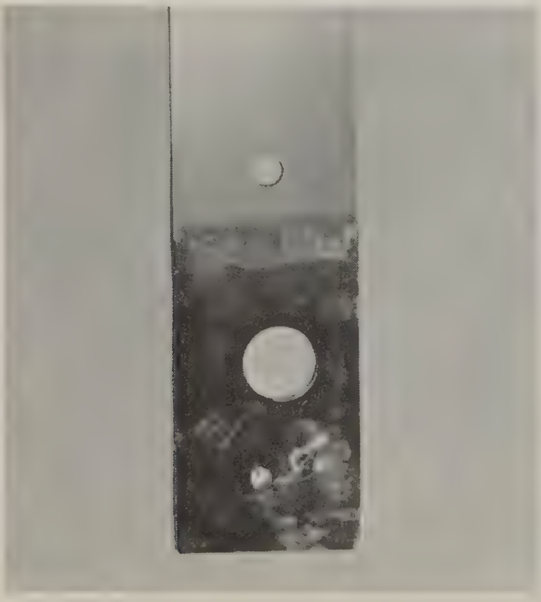


Fig. 8 A pleasing surface may be obtained on polished aluminum by etching material in lye bath. The upper half of this piece has been etched. Note absence of fingerprints and blemishes on the top portion.

Painting Aluminum

For the most part, the painting sequence given previously for steel components can also be applied to the finishing of sheet aluminum. If the metal has a highly polished surface, a much better "tooth" for the finish can be provided by first etching the metal in the manner just described. The caustic solution will also serve to remove grease and dirt from the surfaces.

Before spraying the final finishes on sheet aluminum parts, one or two coats of *zinc chromate primer* (available in an Aerosol spray) should be applied directly to the metal in order to secure maximum paint adherence. After the primer has dried thoroughly, either enamel or lacquer can be employed for the finish coats.

Anodizing Aluminum

In its natural state aluminum appears to be perfectly clean and may seem to defy rusting and corrosion. Actually, as soon as aluminum is exposed to the air a very thin coat of aluminum oxide is formed on the surface. This compound effectively seals the metal against further corrosion under normal conditions. Aluminum oxide is an extremely hard material and is widely used for abrasives. It can be artificially built up to considerable thickness on sheet aluminum by a process known as *anodizing*. This coating hardens the metal surfaces, which are normally quite soft.

When aluminum is to be electrically anodized, the material is connected to the *positive* terminal (anode) of a d.c. supply and immersed, together with the negative electrode, in a bath usually composed of a 5 to 25 percent solution of chromic or sulfuric acid. The passage of electric current causes oxygen to form on the anode terminal. The gas immediately combines with the aluminum to form an aluminum oxide coating which can be built up to as much as a thousandth of an inch in thickness. The oxide coating is smooth and varies from transparent to opaque, depending upon the alloy, processing time, and the solution concentration.

Anodized surfaces as they come from the acid bath are porous, and thus can be dyed various colors if desired. The pores of the aluminum are then sealed by placing the work in a hot water bath (185° to 200°F.) for half an hour. Much of the colored aluminum kitchenware seen in stores these days have been anodized and dyed. Also, most military electronic equipment specifications call for anodizing wherever aluminum is involved. The process makes the metal surfaces highly resistant to corrosion, abrasion, and staining.

The sulfuric acid solution is easiest to employ, as a lower d.c. voltage is required than for the chromic acid treatment. For a sulfuric acid bath, 15 to 20 volts at a current density of 5 to 10 amperes per square foot of aluminum to be processed is normal. Also, the sulfuric acid process provides a better surface for dyeing. The use of sulfuric acid, however, is not recommended for anodizing fabricated parts which have lap joints, such as aluminum chassis bases, as small quantities of the acid may remain in the joints and cause subsequent corrosion. The chronic acid anodizing bath is preferable for components such as these. A 40 volt d.c. supply is required for the chromic acid process, with provision for varying the output from zero to maximum voltage. In addition, a current indicating meter is necessary. Normal current density for this process is 1 to 5 amperes per square foot of work.

Some of the anodizing processes are patented. Additionally, from a practical point of view, the operations are somewhat involved and hazardous for home use. Equipment builders who find it desirable to provide anodized surfaces on electronic equipment foundations might consider having the processing done by firms specializing in such work.

MAINTAINING METAL FINISHES

The surfaces of equipment assemblies should receive occasional attention if they are to remain new looking for long periods of time. This holds true whether the metal is bare or coated, rough or smooth. The frequency of maintenance depends to a large degree upon the conditions and environment to which the equipment is subjected.

Smooth Finishes

Component surfaces which have been finished with smooth lacquer or enamel can be kept in "mint" condition indefinitely by the application of automobile body wax. This simple treatment will produce high resistance to fingerprints and dust accumulation. The modern "hard" wax polishes, such as *Vista* and *J-Wax* provide the most permanent protection. Wax can even be applied to bare metal components such as chassis bases with very good results. Most waxes require hand buffing following application. During project construction, the best time to treat sheet metal components is between the metal working and assembly phases.

All types of finishes, both rough and smooth, can be cleaned by one or a combination of the following methods: (1) Vacuum cleaner hose and soft dry paint brush, (2) damp cloth or chamois, or (3) compressed air jet and paint brush.

Rough Finishes

All of the cleaning methods mentioned above are applicable to rough finishes such as crackle or wrinkle. In regard to waxing, however, one im-

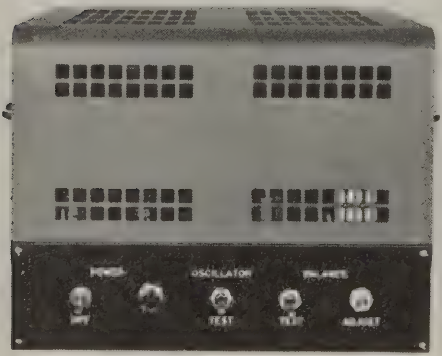


Fig. 9 Commercial electronic gear is often provided with engraved or "silk screened" panel lettering. Home builder may obtain comparable resulits with "decals" (see text).

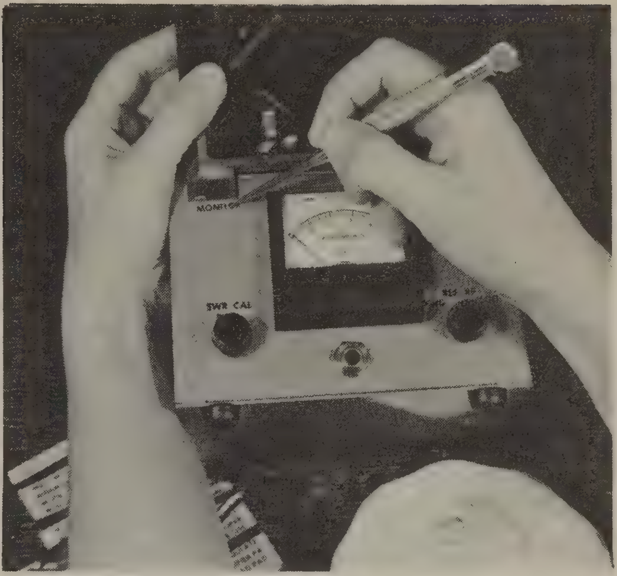


Fig. 10 Carefully applied letter "decals" will do much to enhance the appearance of home built electronic equipment. Positioning of words is facilitated by use of combination square.

portant factor should be noted: combination wax-polishes, such as the two named in the previous section, should *not* be employed on wrinkle finishes, as the polishing ingredient will sink into the "valleys" of the finish and will turn white when dry; this white crust is difficult to remove and results in a pretty sad-looking mess. If any wax is to be used at all on rough finishes it should be of the plain paste type.

It is possible to reduce the dust collecting tendencies of wrinkle finishes by partially filling up the "valleys" on the surfaces. This can be done by spraying several *light* coats of clear lacquer or acrylic plastic over the components. The thin coat will smooth out the surfaces considerably, yet will not change the appearance of the material appreciably. Clear acrylic plastic comes in a pressurized spray can (Aerosol can) and can be purchased at large radio supply stores. It is generally employed for weatherproofing TV and amateur antenna systems.

Wrinkle finished components which have passed beyond the cleaning stage can be renewed by spraying a light coat of black or gray enamel over the surface. Whenever any kind of spray is to be applied to fabricated units, all component parts which are not to be coated should be covered completely with paper and masking tape. All open holes in the chassis should also be masked so that paint will not get onto sub-chassis parts.

PANEL LETTERING

Most factory built electronic units are provided with panel markings to identify controls, meters, and other components. This lettering is usually applied by printing, engraving, *silk-screening*, or by attaching nameplates. A typical manufactured unit, illustrated in Figure 9, is provided with an engraved nameplate which covers the entire front apron of the chassis. This plate consists of laminated bakelite having a white interior sandwiched between thin outside layers of black material. In the engraving process a high speed cutting tool cuts through the black surface, permitting the white to show.

Although most of the industrial lettering methods are beyond the capabilities of the average electronic hobbyist, it is possible for him to achieve professional-like results by employing decal transfers. These are available through all electronic parts suppliers and can be obtained in thousands of different legends, covering many equipment categories.

Directions for the application of lettering decals are supplied with each set. In general, the desired words or phrases are cut out of the sheets on which they are printed. The strips are then immersed in water until the cement softens, permitting the lettering to be slid from the paper backing onto the equipment surface. Proper alignment can be secured by employing the combination square, as shown in Figure 10. As each decal is positioned, the excess water is blotted from the surface. After an overnight drying period, each decal is secured permanently with a *thin* coat of clear lacquer, applied with a small camel hair paint brush.

Decal lettering which has been correctly applied to smooth surfaces can be as permanent as industrial silk-screening or surface printed lettering. Some times, however, it is difficult to obtain satisfactory adherence to wrinkle finishes. In such cases, better results can be secured by first applying a coat of clear lacquer to each individual location to be lettered. The lacquer should be allowed to dry before the decals are put on. A second light coat of clear lacquer should then be brushed over the dried transfer, as mentioned in the previous paragraph.

CHAPTER VII

Component Assembly

Most of the construction details described in the foregoing chapters are of primary concern to the builder who designs his own projects. The chapters which are to follow, on the other hand, will be of equal interest to the kit-assembler. This chapter will consider many of the fundamentals of component assembly, while Chapter VIII will cover details of wiring and soldering.

Hobbyists should take note, at this point, that this material is not intended in any way to replace the assembly information and wiring instructions which are furnished with electronic kits. Instead, its purpose is to provide supplementary information which should help the builder to do a better job. Kit-builders, especially the "new comer," should follow the assembly sequences as outlined by kit manufactures.

HARDWARE

Practically every electronic assembly operation calls for the use of many small items of hardware. Thus, it is important that the hobbyist be able to *recognize* important pieces of hardware and be *familiar* with their application. Illustrated in Figure 1 are examples of various types of hardware which are encountered in electronic work. Each item is identified in the caption.

Most electronic hardware is fabricated from nickel plated steel or brass. Of the two metals, brass is superior because of its better conductivity and resistance to corrosion. Steel, on the other hand, is somewhat lower in cost and is stronger.

Aluminum hardware is also available, but is not often employed in electronic assembly because of its relative softness. It is often utilized to secure other *aluminum* components (such as beam antenna elements) which are exposed to the weather. The use of dissimilar metals in contact under such condition can give rise to corrosion caused by *galvanic* or *battery action.*

Machine Screw Sizes

Machine screws and *hexagonal* (six-sided) *nuts* are the backbone of electronic assembly operations. The sizes most frequently employed by constructors are identified by the numbers 4-40 (or 4-36), 6-32, 8-32, and 10-32. Many newcomers to electronics, and surprisingly enough some "old timers," are unaware of the significance of these size designations, thus the following explanation: A 6-32 machine screw, for example, is not "six thirty-seconds" of an inch in diameter, as is popularly believed. In actuality, the first figure ("6") represents the *outside diameter* of the screw threads,

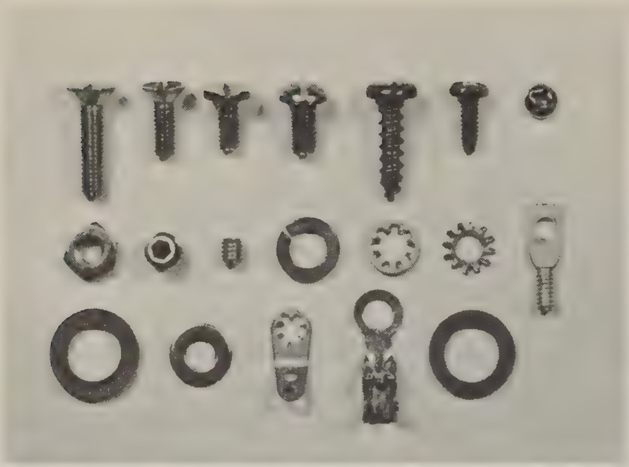


Fig. 1 Hardware items are identified from upper left: Oval head, flat head, binder head, and round head machine screws; two types of self-tapping screws and Phillips head screw. Second row: Hexagonal nut, Allen set screw, slotted set screw, split washer, internal toothed shakeproof washer, flat metal washer, shakeproof washer and spade bolt. Third row: extruded fiber washer, flat metal washer, shakeproof lug, cable clamp lug, fiber washer.

in reference to a standard defined by the tool industry. The second number ("thirty two") indicates the *number of threads per inch.*

Machine screw "number" sizes in relation to actual diameters are given in Figure 2. Dimensions of mating "hex" nuts are also listed. Nut sizes are determined by measuring between opposing flat edges. All nut-driving wrenches are similarly dimensioned.

Whenever machine screws larger than 10-32 are called for the builder will generally shift to *fractional sizes;* for example, ¼-20 or 5/16-18. In such cases the first number indicates the actual screw diameter in fractions of an inch.

Self Tapping Screws

Thread cutting screws are employed extensively in mass production of radio and TV equipment. Chief attributes of these screws are speed of assembly and a considerable savings in material and labor costs. Hardware of this type is seldom used by amateur project builders or by manufacturers of equipment for commercial or military consumption. Self tapping screws cannot ordinarily be tightened as securely as nut-and-screw combinations, especially in thin sheet aluminum because thread stripping is likely to occur. In addition, repeated removal and replacement of self tapping screws will have the same effect, unless the original threads are engaged each time.

Self tapping screws are very useful in special cases, such as in "blind" assembly operations where it is impossible to employ nuts. Installation of self tapping screws can be facilitated by coating the threads with beeswax or paraffin.

FIG. 2 – MACHINE SCREW SIZES

SCREW SIZE	MAJOR DIAMETER	NUT SIZE
2	.086	3/16"
4	.112	1/4"
6	.138	1/4" OR 5/16"
8	.164	11/32"
10	.190	3/8"
12	.216	3/8"

EXTRUDED FIBER WASHERS

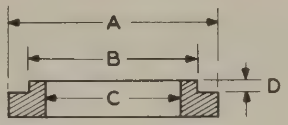


Fig. 3 Extruded fiber washers of this type are used for insulating control bushings from metal panel or chassis. Metal is drilled to clear dimension "B".

A	B	C	D	SCREW SIZE
5/16"	.187	.140	1/32"	6
3/8"	.250	.169	"	#8
7/16"	.255	.196	"	#10
1/2"	.375	.250	"	1/4" *
5/8"	.437	.380	"	3/8" * *

* CONTROL SHAFTS
* * CONTROL BUSHINGS

Lock Washers

Three different styles of *lock washers* are illustrated in Figure 1. Included are the *split* type and the *internal* and *external shakeproof* varieties. The chief function of a lock washer is to prevent loosening of other hardware. Thus, lock washers should be employed in all electronic equipment, especially that which is subject to vibration. In addition, the sharp teeth of the shakeproof washers tend to cut through paint and oxidation, thus making good electrical contact between components and foundation.

Fiber Washers

Two varieties of *fiber washers* are shown in Figure 1. One is a plaint, flat washer. The other which has a projection around the inner circumference is known as a *shoulder* or *extruded washer*. These are generally employed in combination whenever it is necessary to insulate hardware or control bushings from sheet metal surfaces. Shown in Figure 3 are extruded washer dimensions. Sheet metal parts should be drilled to clear dimension *B*.

Spade Bolts

Spade bolts are designed to facilitate mounting sheet metal parts at right angles to each other. Application of this hardware item is illustrated in Chapter IV.

HARDWARE ASSEMBLY

During assembly and wiring operations electronic equipment can often be supported by its own components. If there is a possibility of damaging fragile parts, however, then it is advisable to support the work in some other manner. Figure 4 illustrates an excellent method, as applied to a *Viking Ranger* transmitter kit. The home made wooden legs, which are attached to the rear corners of the chassis, permit any convenient positioning of the assembly without danger of component damage. In the absence of a front panel four legs should be employed.

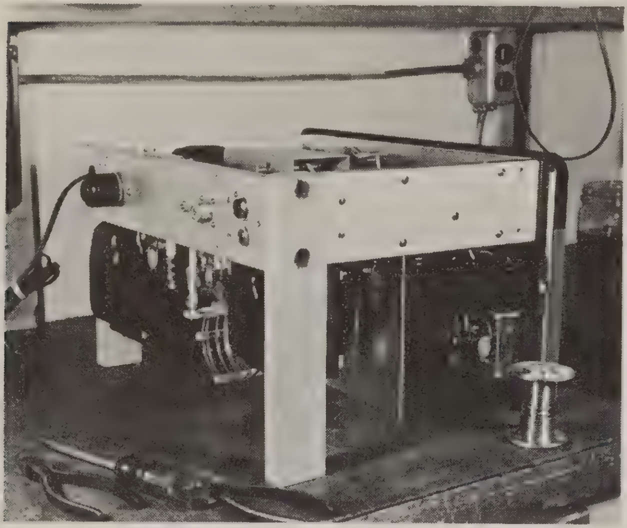


Fig. 4 Equipment assembly can be facilitated and danger of damage to components minimized by use of temporary wooden chassis legs as employed on this transmitter.

Hardware Assembly Sequence

The correct assembly procedure for electronic components and associated hardware is pictured in Figure 5. There are a few exceptions, however, especially involving ceramic parts, which will be discussed individually.

In the sequence shown in Figure 5A, one additional shakeproof washer should be employed between the chassis and each foot of the component, as indicated by *X*, if the chassis or component feet are painted. This will provide better grounding of the component. In Figure 5B, an extra shakeproof washer should be placed under each screw head if the component flanges are painted.

Hardware assembly is best accomplished by using a screwdriver and a *spintite socket wrench*. Tightening should be done by *rotating the wrench* while holding the screwdriver stationary. This results in a tighter assembly and will minimize screw slot damage. If a socket wrench cannot be used, as is frequently the case where miniature tube sockets are involved, secure the hardware by grasping the nut with long nose pliers and tighten the machine screw with a screwdriver of suitable size.

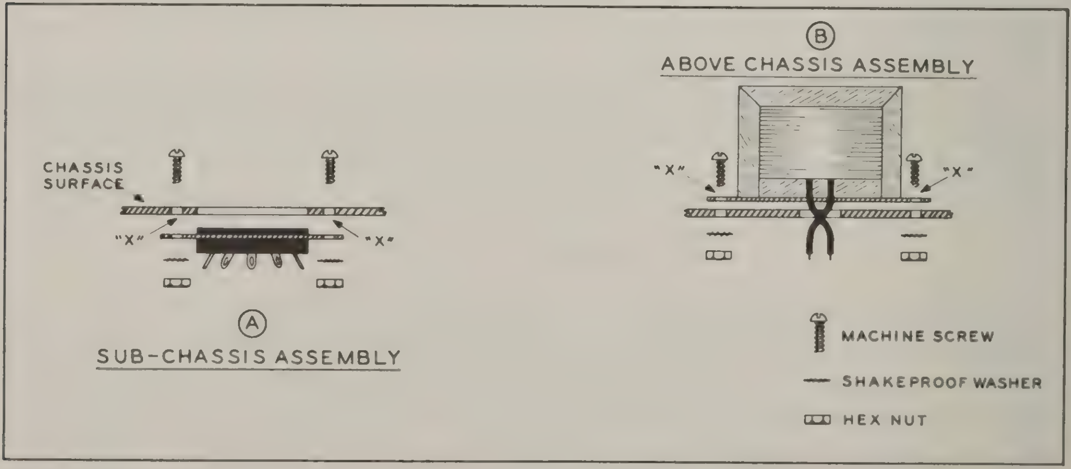
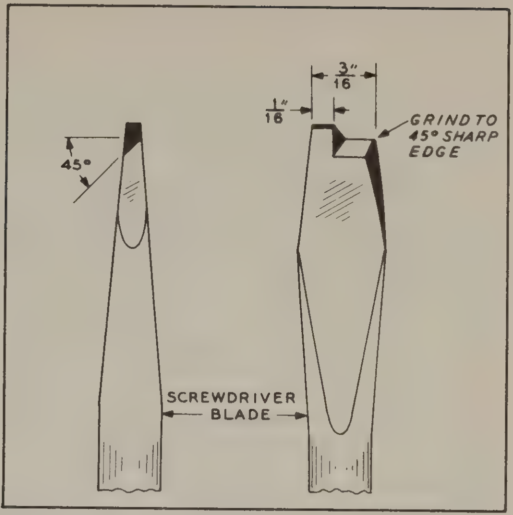


Fig. 5 Assembly sequence for sockets and small parts. If surfaces are painted, clean and use shakeproof washers between parts as shown at "X" (above).

Fig. 6 A handy tool for stripping paint from around small holes can be made from an old screwdriver. The blade is ground as shown.



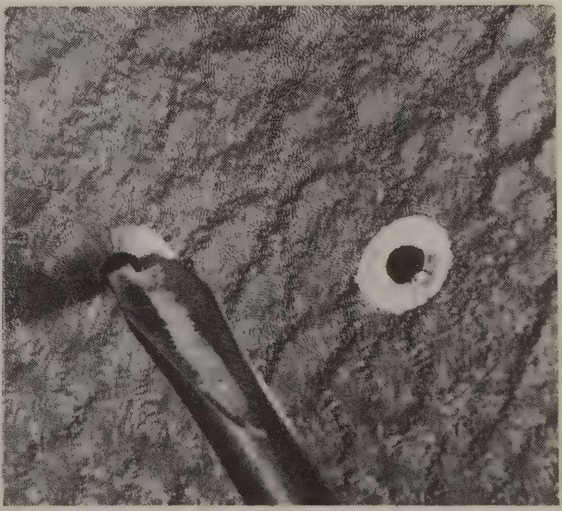
Stripping Paint From Mounting Screw Holes

Whenever chassis bases are coated with paint it is best to strip the finish from the area around mounting screw holes to provide the best possible electrical contact at these points. This can be accomplished by scraping the paint with a knife, although the job can be done much more efficiently and neatly by employing a *paint stripper*. Such a tool can be fashioned from an old screwdriver, with the end of the blade ground as shown in Figure 6. In operation, the tip of the tool is inserted in a mounting screw hole and rotated until the paint has been stripped cleanly, as illustrated in Figure 7.

COMPONENT ASSEMBLY

During kit assembly, components should be carefully positioned as specified in the instructions. Faulty orientation of parts in some cases can often be disasterous. Whenever possible, the component parts in home designed equipment should be oriented so that the shortest possible wiring leads will result (especially plate and control grid connections). Although this is not particularly critical where d.c. and audio frequency circuits are concerned, it is important at radio frequencies, and becomes increasingly so as the frequency rises.

Fig. 7 Stripping paint from mounting screw holes can be done rapidly with this home made tool



Assembly Order

Kit assembly sequences are always set down in black and white by the manufacturer, so there should be no question as to the order of component mounting. Where home designed equipment is involved, however, it would be impractical to do more than generalize on the sequence of part assembly. The operations which are included under this heading have been organized in a maner conducive to maximum efficiency, and minimum wear-and-tear on the builder!

Retainer Ring Sockets

It is almost mandatory that retainer ring tube sockets, such as *Amphenol Series "S"* and *Cinch Type "R"* be mounted to the chassis before any other components, as installation of these sockets cannot easily be accomplished unless the chassis is inverted and placed flat upon the bench top. Assembly procedure is as follows:

1—Insert socket in chassis hole. Hold socket in place, invert chassis and lay on flat surface.

2—Position socket as desired. Make certain that socket is completely seated in hole. (If chassis metal is thin, or if twisting of socket is likely to occur, it is best to use "keyed" hole punch as discussed in Chapter IV).

3—Place retainer ring on rear of socket and press down with fingers so that ring expands and slips over socket body.

4—Using screwdriver blade, press down on lower overlapping portion of retainer ring until it snaps into groove in socket (see Figure 8). Continue pressing around circumference of retainer ring until entire perimeter of ring has snapped into position.

Miniature Retainer Ring Sockets

A smaller type of retainer ring socket employs a locking ring which is provided with sharp, internal teeth. When the ring is pressed into position the teeth bite into the plastic body of the socket, thereby holding the assembly in place. Sockets of this type, such as the *Amphenol Series 78,* can

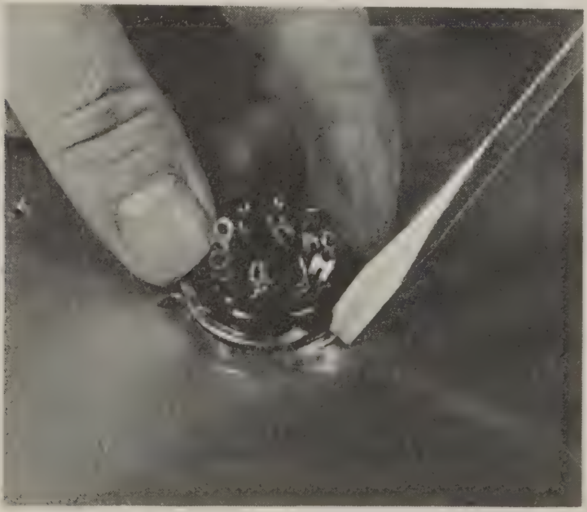
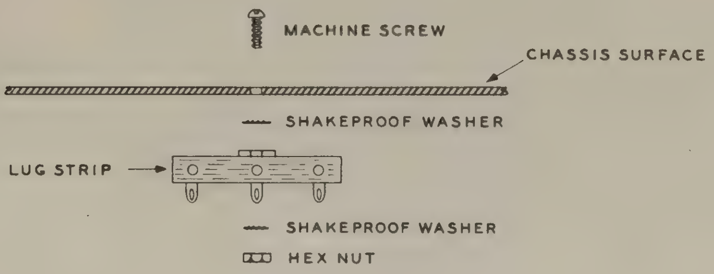


Fig. 8 Press overlapping portion of socket retainer ring with screwdriver blade until ring snaps into groove in socket body.

FIGURE 9

MOUNTING TERMINAL-LUG STRIPS TO CHASSIS



be mounted in 5/8″ round, or "D"-shaped holes (the latter will prevent socket rotation). Assembly is accomplished in much the same manner as described in the previous section, except that the ring is simply positioned on the socket with the teeth pointing away from the chassis, then pressed into place. Once in position, this type of ring is very difficult to remove as the teeth tend to dig into the socket with any such attempt.

Screw Mounted Sockets

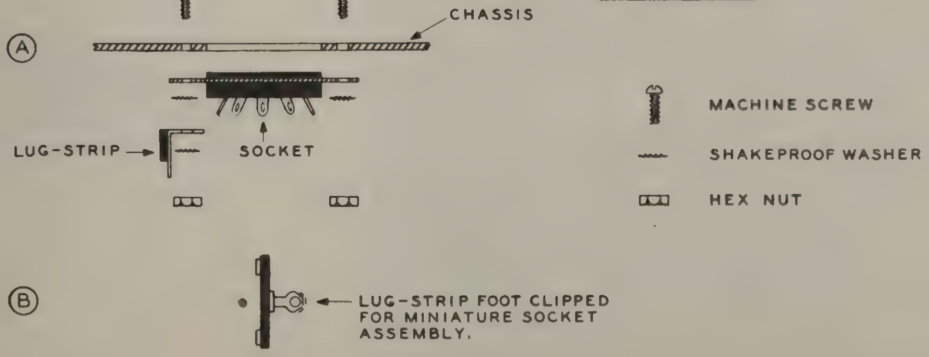
Screw mounted sockets present no particular assembly problems. Most standard sized tube sockets are mounted with 6-32 x 1/4″ machine screws, nuts, and shakeproof washers, in the manner illustrated in Figure 5A. Miniature sockets frequently are provided with mounting screw holes having maximum clearance for #2 screws. If the builder desires to employ larger screws (perhaps #4) for assembly, the holes must be enlarged. This is best accomplished by using a *taper pin reamer* as illustrated in Figure 12.

Terminal Lug Strips

Single foot *terminal strips* may be secured by tube socket mounting hardware. Thus it is frequently convenient to assemble these items simultaneously. Other lug strips can also be mounted at this time, if desired.

FIGURE 10

MOUNTING LUG-STRIPS TO SOCKETS



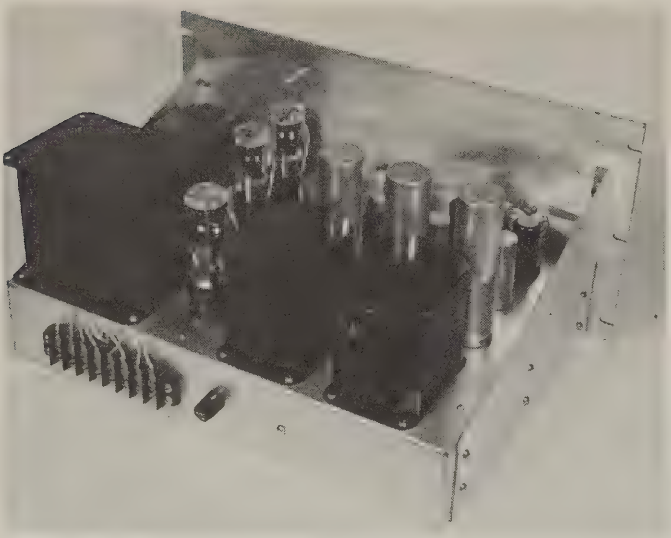


Fig. 11 Heavy panel-chassis units should be braced by use of side brackets.

Assembly of single foot lug strips to the chassis should be accomplished in the manner shown in Figure 9. The extra shakeproof washer between the foot and the sheet metal surface will prevent the lug strip from rotating when the hardware is tightened.

The procedure for assembling single foot lug strips to socket hardware is illustrated in Figure 10A. Whenever miniature tube sockets are involved, it will generally be necessary to reduce the size of lug strip feet so as to clear the edges of the sockets. This can be done by clipping the foot with diagonal wire cutters (Figure 10B).

Mounting Heavy Components

Once the heavier components have been secured to a chassis, handling of the assembly becomes difficult. Therefore it is generally advisable to mount as many of the smaller parts as possible before going to the larger ones, such as power transformers and iron core filter chokes.

Choice of hardware for bulky parts depends upon weight and mounting hole size. For average sized components, 8-32 to ¼-20 machine screws are generally suitable.

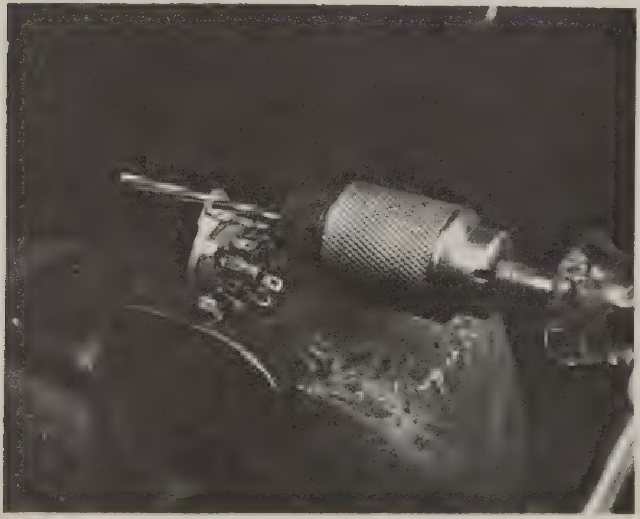


Fig. 12 Small holes in parts can be enlarged without tearing the metal by drilling with taper pin reamer.

Fig. 13 Taper pin reamer may be used in hand drill to enlarge holes to pass machine screws.

FIGURE 13–TAPER PIN REAMERS

SIZE	MIN. DIA	MAX. DIA.
7/0	.0497	.0666
6/0	.0611	.0806
5/0	.0719	.0966
*4/0	.0869	.1142
3/0	.1029	.1302
*2/0	.1137	.1462
0	.1287	.1638
*1	.1447	.1798
2	.1605	.2008

*–*MOST USEFUL SIZES FOR ELECTRONIC WORK.*

Assembling Panel and Chassis

Where small or medium size chassis-and-panel assemblies are being constructed, and four or more control bushings are to pass through both the chassis apron and front panel, the hardware of these components will serve to secure the two foundation parts together. In all other cases, machine screws, lockwashers, and nuts should be used to complete the assembly. If considerable weight is to be supported by the chassis and panel, or the unit is to be rack mounted, it is advisable to strengthen the assembly by employing *mounting brackets* as illustrated in Figure 11.

Other Components

Unless it is inconvenient, the assembly of fragile components such as coils, variable capacitors and meters should be delayed until after all heavy parts have been mounted in order to minimize the possibility of damage.

All small parts, including resistors, fixed capacitors, and the like, are more properly classified as wiring components and should be installed during the wiring process.

Enlarging Small Holes in Thin Metal

Frequently the hobbyist may find it necessary to enlarge small holes in thin metal. In most cases it is virtually impossible to enlarge the holes by employing twist drills without tearing the metal. The most satisfactory method thus far discovered by the author calls for the use of *taper pin reamers.* These can be purchased from machine tool dealers, and although fairly expensive, will last a lifetime if not abused.

Reaming small holes is best accomplished by hand, as illustrated in Figure 12. Practically no forward pressure is necessary or desirable. Cutting action is obtained in the clockwise direction, the same as for twist drills. Taper reamer sizes from 7/0 to No. 2 are tabulated in Figure 13. The 4/0, 2/0, and No. 1 sizes are the most useful for hobbyists. The dimensions overlap and will ream clearance holes for Numbers 4, 6, and 8 machine screws, respectively.

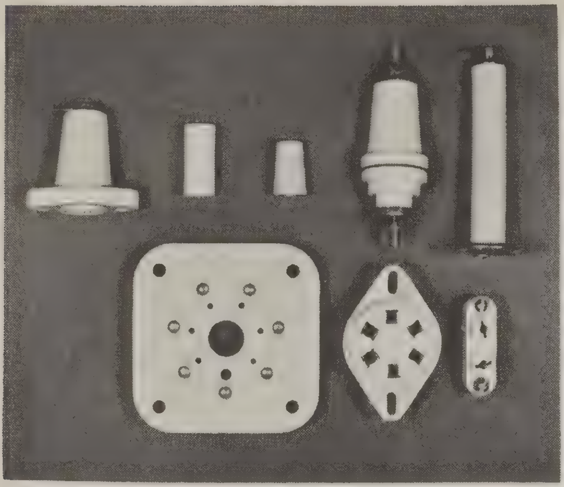


Fig. 14 Ceramic components (from upper left) are: Cone standoff insulator with untapped mounting holes in feet, pillar and cone insulators with tapped ends, feed through insulator and standoff insulator with metal base. At bottom: Transmitting tube socket, receiving tube socket and crystal holder.

Assembling Ceramic Components

The *ceramics*, such as *porcelain* and *steatite*, are virtually as hard and unyielding as glass. Care must be exercised in mounting ceramic components so that no undue strain will be placed upon the material. Cushioning can be accomplished by employing soft fiber washers between ceramic and metal surfaces. Where standoff and feed through insulators are used, it is best not to assemble wiring or mount other circuit components under the hardware used to secure the ceramic parts. Additional hardware should be provided for terminations, as shown in Figures 16 and 17.

Ceramic Sockets

Some ceramic sockets such as the transmitting type (Figure 14) are mounted directly to metal surfaces. These should be attached in the manner illustrated in Figure 15. Hardware should be tightened carefully, so that the ceramic material will not be broken. Most receiving type ceramic sockets are provided with metal mounting plates, and the use of fiber washers is not required.

Standoff Insulators

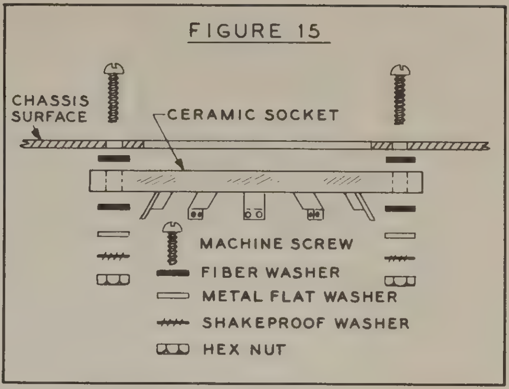
Ceramic standoff insulators are grouped into three classes (Figure 14): (1) Cones, having non-threaded mounting holes cast into the ceramic flanges or "feet," (2) Cones or pillars, having internally threaded end holes, and (3) Pillars, fitted with metallic mounting flanges and terminal hardware.

Breakage is seldom a problem where insulators of the third category are involved, and mounting can be accomplished in the manner pictured in Figure 5.

Ceramic flange insulators were once very popular, and in fact, once were about the only varieties available. These are frustratingly easy to break, however, and their use has declined in favor of the other two styles.

Large diameter cone or pillar insulators of the internally threaded type can be mounted in direct contact with metallic surfaces without danger of breakage. If insulator diameters are ½-inch or less, it is generally best to

Fig. 15 Ceramic sockets without metal mounting plates should be protected against strain by use of fiber washers between surfaces.



employ fiber washers, as illustrated in Figures 16B and 16C. In all cases, machine screws should be of adequate length so that at least three-quarters of the insulator threads will be engaged when the hardware is tight. At Figure 16C, the threaded stud should be long enough so that it can be screwed all the way to the bottom of the insulator and still accomodate the terminal hardware. The bottom nut should be tightened securely, and all terminal connections assembled between the two upper flat metal washers.

Feedthrough Insulators

Ceramic feedthrough insulators are employed whenever it is necessary to conduct high d.c. or r.f. voltages through metallic partitions. Insulators of this type are manufactured in many different sizes and shapes, some as small as buttons, others a foot or more in diameter. The typical feedthrough insulator consists of two mating halves through which passes a long, threaded stud.

The assembly sequence for feedthrough insulators is shown in Figure 17. In every instance, the hole in the partition must be large enough to clear the ceramic bushing on the male half of the insulator. The inner nuts are tightened securely and left undisturbed thereafter. Terminal connections should then be made between the outside pairs of flat metal washers.

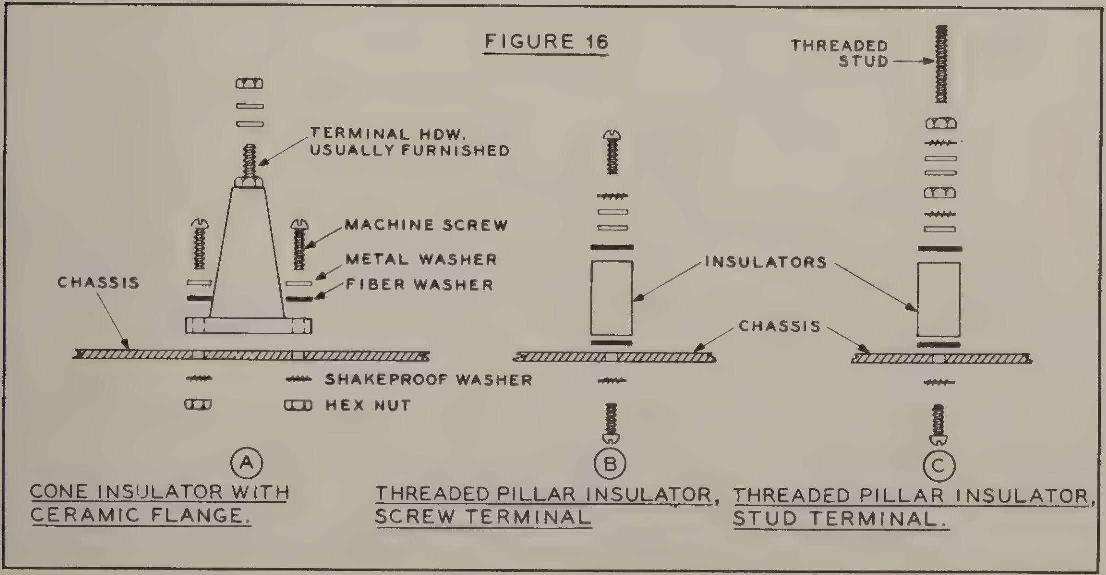


FIGURE 16
TERMINAL HDW. USUALLY FURNISHED
MACHINE SCREW
METAL WASHER
FIBER WASHER
CHASSIS
SHAKEPROOF WASHER
HEX NUT
THREADED STUD
INSULATORS
CHASSIS
Ⓐ
CONE INSULATOR WITH CERAMIC FLANGE.
Ⓑ
THREADED PILLAR INSULATOR, SCREW TERMINAL
Ⓒ
THREADED PILLAR INSULATOR, STUD TERMINAL.

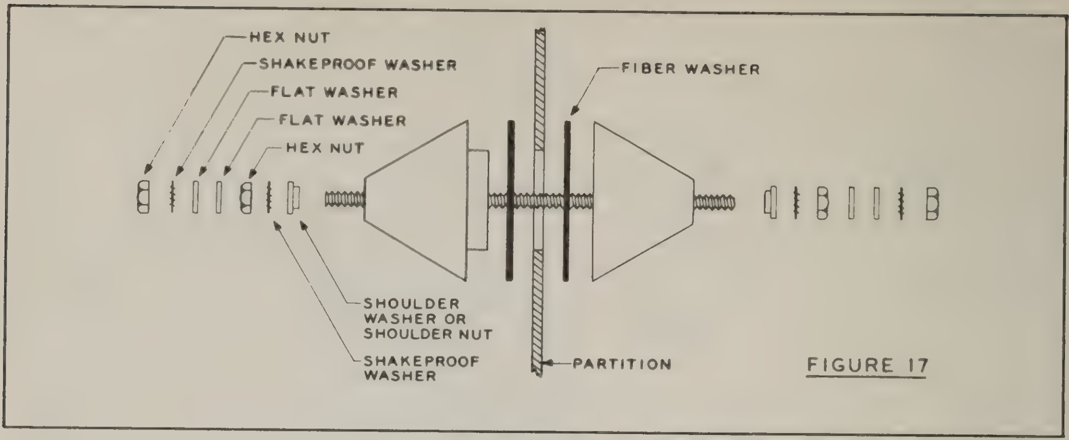


FIGURE 17

Ceramic Coil Forms

Figure 18 illustrates both vertical and horizontal chassis mounting of tubular ceramic coil forms, plus associated hardware assembly order.

If a coil form is to be mounted vertically (Figure 18C) hardware should be assembled in the manner pictured in 18A or 18B. The latter method requires the constructor to exercise a bit more care because of the greater possibility of fracture. In order to reduce this hazard, yet avoid loosening of hardware, the "jam-nut" principle should be employed. This can be accomplished by first assembling the hardware, as illustrated, then tightening the inner nut securely but carefully. Jam the outer nut against the inner one by holding the latter with a small end wrench and tightening the former with a spintite socket wrench.

Ceramic coil forms may also be mounted parallel to a chassis or panel, as shown in Figure 18E. Internally threaded metal spacers, or ceramic standoff insulators are usually employed as supports and these should be assembled in the maner pictured in Figure 18D.

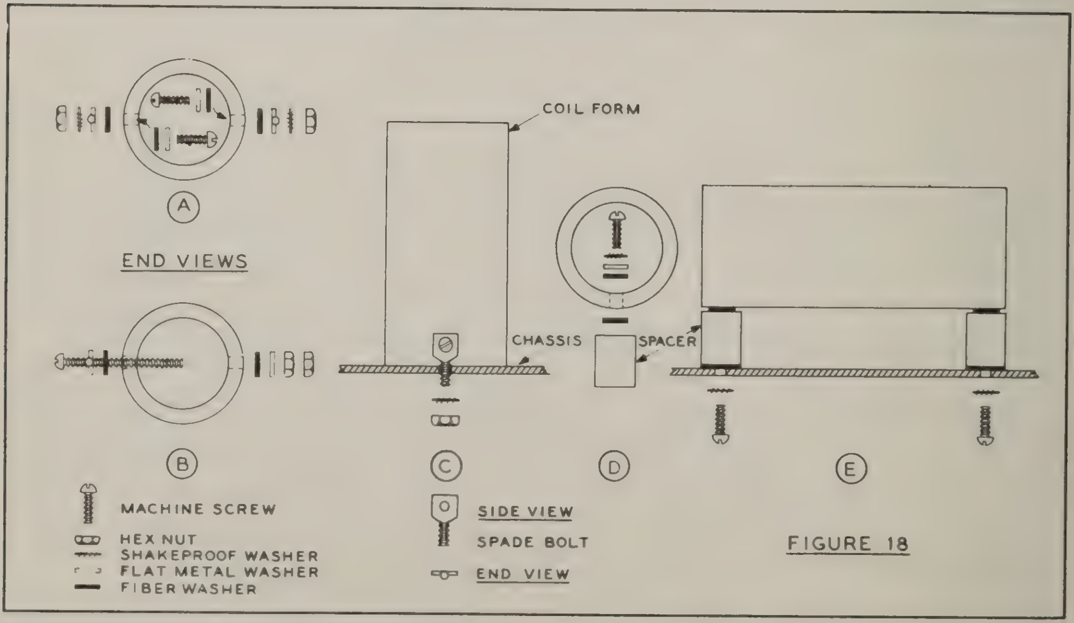


FIGURE 18

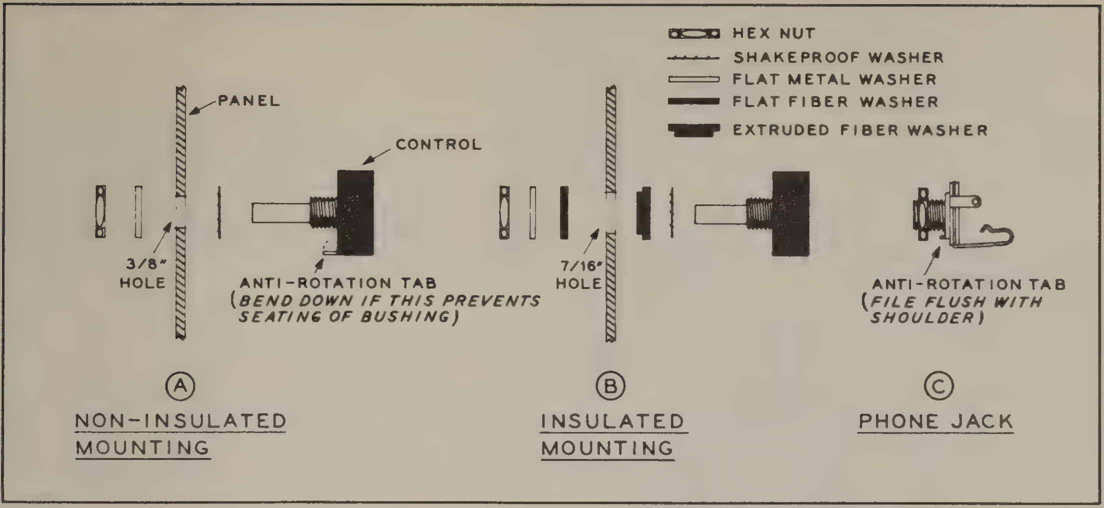


Fig. 19 Panel controls are mounted to metal surfaces. If insulated mounting is desired, the sequence shown above is used. Anti-rotation tab is filed off.

Mounting Panel Controls

A large percentage of the panel controls used in electronic equipment are provided with ⅜-inch diameter threaded bushings. Typical examples are: potentiometers, phone jacks, panel bearings, rotary switches, small variable capacitors, etc. Whenever these are to be mounted directly to a chassis or panel, the assembly sequence illustrated in Figure 19A should be employed. The flat metal washer prevents marring the sheet metal finish, while the lockwasher eliminates loosening and turning of the component. If a control has been fitted with an extra long bushing, placement of an additional nut between the shakeproof washer and the bushing shoulder will reduce frontal projection of the control bearing.

Inspection of almost any potentiometer will show that it is provided with one or two small tabs which project forward from the case. These projections prevent rotation of the control case when assembled in mass produced radio and TV sets. As far as the hobbyist is concerned, however, the tabs have no useful purpose and may even obstruct assembly. If this is so, bend them down against the control body or file them flush with the bushing shoulders as indicated in Figure 19C.

Insulated Panel Controls

Certain circuits require panel controls to be insulated from the foundation or chassis. In such cases, the hardware sequence of Figure 19B should be followed. *CAUTION:* If potentials above 50 volts exist on non-grounded controls, it is essential that *only insulated knobs* be employed. Set screws should also be recessed sufficiently so that bodily contact is impossible. If potentials exceed 250 volts (as may be the case in some TV and oscilloscope applications), insulated bushings and shafts such as the *Clarostat #59-186* and *#RN-3* must be employed. The practice of wiring phone, metering or keying jacks into high voltage circuits is dangerous, and should be avoided.

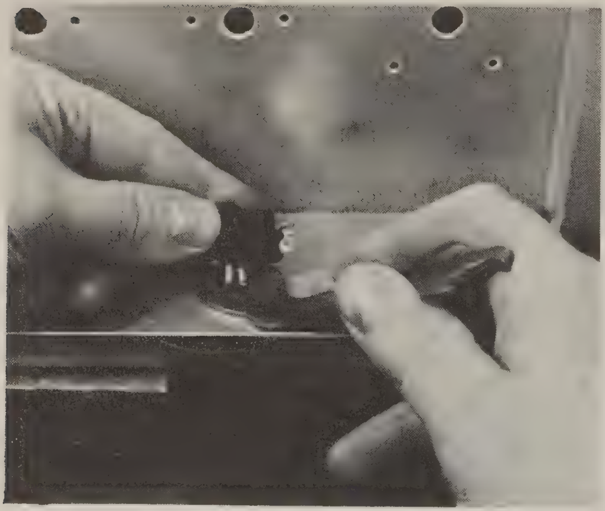


Fig. 20 Toggle switch is secured by tightening rear nut rather than knurled panel nut. Thin, open end wrench is used for this job.

Toggle Switch Mounting

Toggle switches are manufactured in a wide variety of models, and practically all are fitted with standard 15/32-inch diameter bushings, and can be mounted in ½-inch holes. Assembly hardware is generally supplied with each switch, and consists of a knurled nut and one hex nut. (Shakeproof washers are seldom furnished except on "aircraft" types).

Toggle switches are usually assembled with the knurled nut on the outside of the panel and the hex nut inside. Special socket wrenches are available for knurled toggle switch nuts, although it is generally just as convenient to assemble the hardware with the fingers, positioning the knurled nut as desired, then tightening the rear hex nut with a wrench while holding the switch in position (Figure 20).

A thin, stamped, metal wrench of the double open end type (7/16″ and ½″ openings) makes an excellent assembly tool for toggle switches and other types of controls. The wrench heads should be offset about 30 degrees so that chassis lip clearance can be obtained. Tightening knurled toggle switch nuts with pliers is to be discouraged, as damage to sheet metal surfaces or mounting nuts is almost certain to occur.

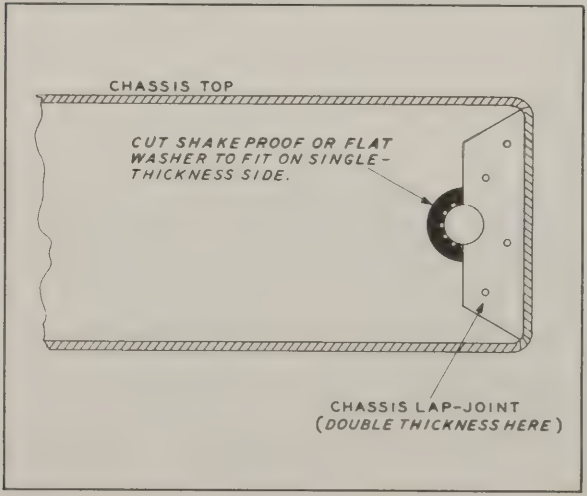
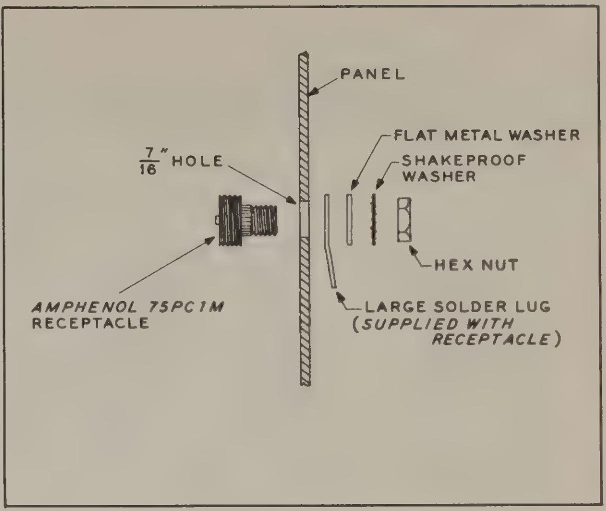

CHASSIS TOP
CUT SHAKEPROOF OR FLAT WASHER TO FIT ON SINGLE-THICKNESS SIDE.
CHASSIS LAP-JOINT (DOUBLE THICKNESS HERE)

Fig. 21 In order to have proper seating of control at chassis lap joint it is necessary to build up single thickness area by cutting washer to fit, as pictured.

Fig. 22 Coaxial microphone connector is panel mounted. Knurled shank prevents the connector from rotating.


PANEL
FLAT METAL WASHER
$\frac{7}{16}$" HOLE
SHAKEPROOF WASHER
HEX NUT
AMPHENOL 75PC1M RECEPTACLE
LARGE SOLDER LUG (SUPPLIED WITH RECEPTACLE)

Mounting Controls at Chassis Lap Joints

Occasionally, the hobbyist may find it necessary to mount a panel control near a chassis corner where the overlapping sheet metal joint occurs. If the mounting hole cuts through both the double and single thickness sections of metal, and more than half is on the single thickness side, this portion must be built up in order to obtain square seating of the bushing shoulder. Figure 21 depicts an interior view of a chassis apron. Uniform metal thickness at the lap joint can be obtained by cutting a shakeproof or flat metal washer then fitting it into position during assembly of the component part.

Microphone Connectors

Several types of microphone connectors such as the *Amphenol Series 75 and 80* (chassis mounted receptacles) are provided with threaded bushings which terminate in knurled collars, as shown in Figure 22. Mounting holes for these components should be drilled and reamed, if necessary, so that the knurling will fit the hole tightly enough to prevent rotation. Assembly is as follows:

1. Assemble components finger tight.
2. Wrap front part of receptacle with four or five layers of masking tape (to protect threads from pliers.)
3. Grip taped part with slip joint pliers. Tighten rear hex nut with wrench. Remove masking tape.

Pilot Light Assemblies

Pilot light assemblies are manufactured in *right angle* and *coaxial* styles (Figure 23). Of the two varieties, the coaxials are most popular as bulb replacement can be accomplished without the necessity of gaining access to the interior of the electronic unit. One needs only to remove the *jewel* in order to change bulbs. This job can be facilitated by employing the special bulb replacement tool, illustrated in Figure 23. The tool is made of soft rubber, and will handle miniature T-3¼ and 110 volt, S-6 bulbs.

The constructor may find it difficult to tighten pilot light assemblies

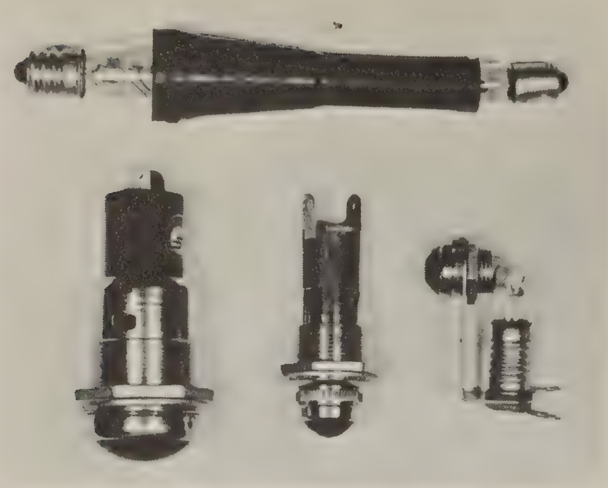


Fig. 23 Shown are several types of pilot light assemblies, including two in-line and one right angle variety. Changing pilot lamps is facilitated by use of a rubber bulb replacement tool (top).

during installation. This operation can be facilitated by employing the following method, which is especially applicable to the coaxial varieties of lamp assemblies.

1. Insert lamp socket in mounting hole. Assemble hardware and secure large hex nut finger tight.
2. Wrap four or five layers of masking tape around threaded bushing or around housing in back of bushing.
3. Grasp taped area with slip joint pliers to prevent rotation of assembly. Tighten hex nut securely, with offset end wrench as illustrated in Figure 24. Remove masking tape.

CHASSIS MOUNTED, PANEL CONTROLLED PARTS

In the construction of high frequency electronic units it is often necessary or desirable to mount panel controlled components to the chassis. Figure 25 illustrates a typical case, frequently encountered in amateur and commercial radio transmitters involving the mounting of a variable capacitor on which high voltage is present. In any assembly of this type, all

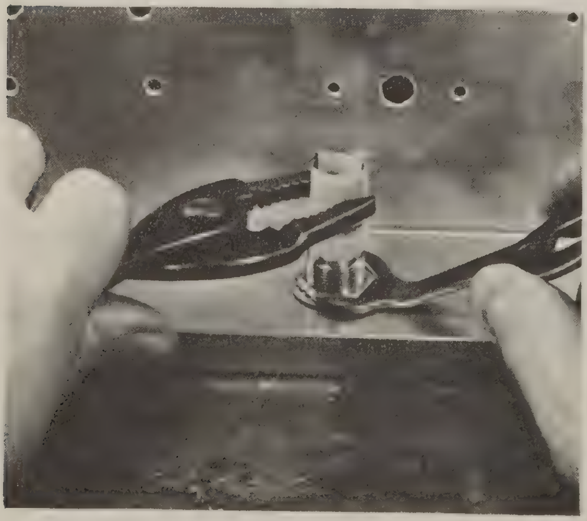
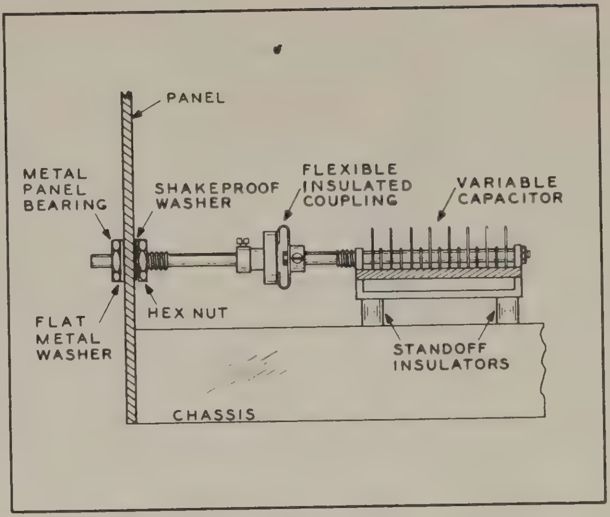


Fig. 24 Securing pilot light assembly is aided by wrapping housing with masking tape, then gripping tape with pliers while hex nut is tightened with offset, open end wrench.

Fig. 25 High voltage variable components may be insulated from chassis by standoff insulators. Insulated coupling and shaft protect the operator from shock. A grounded metal panel bushing should be employed.



insulators including the shaft coupling should be able to withstand at least twice the maximum peak voltage which will ever appear between the component and the chassis. In amplitude modulated r.f. stages, the peak voltage may be as much as four times the applied d.c. voltage.

CAUTION: Always employ a *grounded metal panel bearing*, never an insulated one, as the latter could conceivably permit the extension shaft to conduct lethal voltages to the control knob and thence to the operator. In addition, it is possible for an ungrounded shaft to carry r.f. voltages outside of shielded enclosures thus increasing the possibility of energy radiation and television interference (TVI).

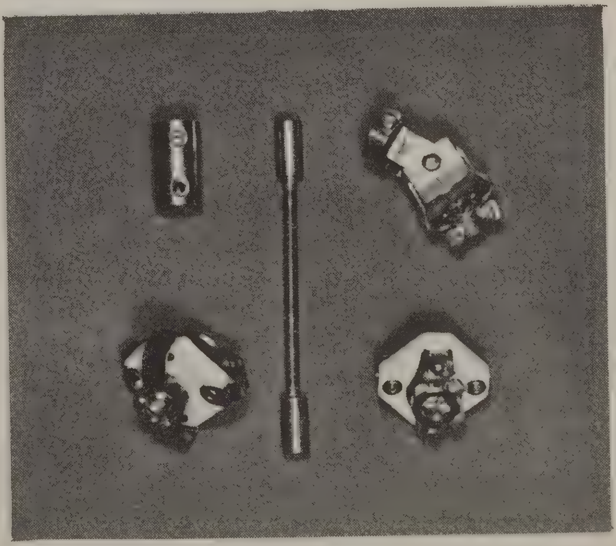
Shaft Couplings

Many types of shaft couplings are manufactured in both metallic and insulated varieties. Some examples are illustrated in Figure 26. Specific applications of the various couplings include:

Rigid: Employed where shafts are in perfect or near perfect alignment and where end play is not a problem.

Flexible: Used for connecting shafts which are slightly out of angular or axial alignment, or where some shaft end play exists.

Fig. 26 Shown are typical shaft couplers. Upper left: rigid metal coupling. Upper right: insulated universal joint. Lower left: insulated flexible coupling. Lower right: insulated, offset coupling. Center: flexible shaft.



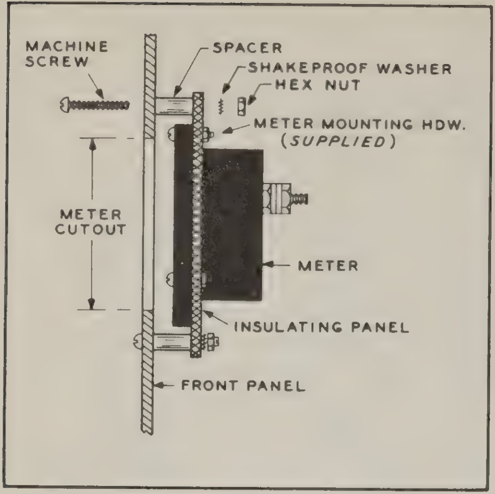


Fig. 27 The panel meter should be placed in circuit at or near ground potential. Instruments in high voltage circuit should be insulated from ground and mounted so that accidental contact cannot occur. Shown is meter recessed behind panel. Cutout may be covered with protective glass or plastic.

Offset, or Slide Action: Employed for joining shafts which are considerably out of axial alignment. Can also handle shaft end play, and angular misalignment.

Universal Joint: Used for angular drive, up to 45 degrees.

Gear Assembly: Generally employed for 90 degree drive.

Flexible Shaft: Used in cases where physical spacing and/or shaft misalignment prohibit employment of other types of couplings. Not suitable if tracking between control knob and component is important.

Mounting Panel Meters

Although panel meters are rated to withstand about 500 volts between movement and ground, it is usually possible to design electronic circuits so that potential differences between meter and chassis will be much lower than that. Most meters, therefore, can be mounted directly to metal panels. Occasionally it may be necessary to insert a meter into a high voltage circuit and in such a case it is advisable to assemble the instrument to a sheet of insulating material which is then secured behind the front panel opening as illustrated in Figure 27. If the need exists, the observation hole in the panel can be sealed against r.f. leakage by mounting a piece of screen on the back side, making certain of complete electrical contact around the circumference of the opening.

TVI-Proofing Meters

Meters which are mounted directly to front panels in radio frequency units may be TVI suppressed by shielding and filtering, as shown in Figure 28. (Metal cased meters do not require shielding, but may need filtering.) A suitable shield can be fabricated from an aluminum cup or tin can end of suitable diameter in the following manner:

1. Set combination square head to dimension *A*, plus ⅛″. Mark a line around circumference of cup. Re-position square to dimension *B* (dimension *A*, minus ⅜″). Mark a second line around cup. (Dimension *A* is distance between back of panel and rear of inner fiber-washer on meter terminal.)

2. Cut aluminum cup to size, employing circle cutting tin snips and "spiraling" in from outer edge. Smooth rough edge with fine, flat file, or side of grinding wheel.

3. Make "fingers" by clipping edge of cup with diagonal wire cutters. Cuts should be made at *line B*, and be about ¼″ apart. Bend all fingers outward about 45 degrees.

4. Mark and drill holes for terminals and lug strip. Terminal holes should be large enough to clear shoulders on extruded fiber washers. (Drilling is best accomplished by starting with a small drill and working up to desired size in small steps. This will minimize possibility of tearing metal).

5. Mount a 3-lug terminal strip (center lug grounded to foot), as shown in the illustration.

6. Assemble shield to meter, positioning hardware as shown. If contact fingers exert too much pressure, bend outward slightly. Back of panel must be paint-free around finger contact area.

CONTROL SHAFTS AND KNOBS

Panel controls are very frequently provided with long shafts which often must be cut to more suitable lengths. Specifically, this can be done by first determining the depth of the hole in the knob to be employed, then by cutting the shaft to this dimension. After being cut, the end of the shaft should be smoothed and beveled with a file or grinder.

Securing Knobs

One problem all too often encountered by builders is the tendency for control knobs to slip on the shaft. This is especially true where high torque components such as rotary selector switches are involved. Following are some solutions to this problem:

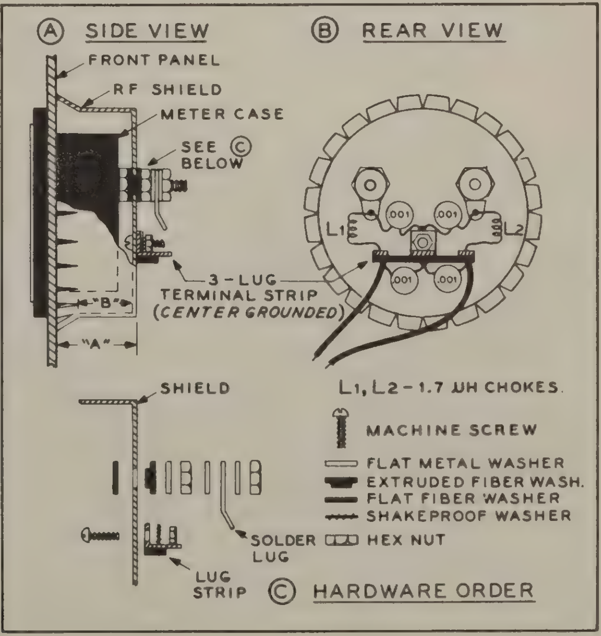


Fig. 28 Bakelite meters may be TVI suppressed by use of proper shielding and filtering. Shield is made from metal cup and the leads are filtered by VHF chokes (L1 and L2) and capacitors. Foot of lug strip is grounded to meter shield.

1. Employ knobs made of hard bakelite, or those which are provided with metal inserts, wherever possible. Avoid use of soft thermoplastic knobs which do not have metal bushings as it is often impossible to tighten set screws securely enough without stripping threads.
2. If set screws cannot be tightened adequately, slipping can be minimized by filing a flat on the control shaft when positioning the knob so that the set screw engages the flat. (Whenever accuracy of knob pointer setting is important, determine proper position for flat before filing.)
3. Knob slippage can often be eliminated by replacing slotted set screws with *Allen set screws.* More leverage can be obtained from an *Allen wrench* than from a screwdriver. Allen set screws should only be employed in knobs which have metal inserts.
4. Where large knobs are involved, use those which are provided with two set screws instead of a single one.

MOUNTING FUSES

Although much commercially built equipment and many electronic kits lack individual primary fusing, it is wise to provide all units with such safeguards. Most house wiring circuits are fused for 15 amperes, which is generally much too high to provide any measure of protection where small equipment is concerned.

Three different fuse mounts are pictured in Figure 29. The *extractor* and *fused plug* mounts are most popular with project builders, because of the ease of fuse replacement. Because of the shock hazard, it is generally necessary to locate open type *fuse clips* inside of electronic units, seriously limiting fuse accessibility.

The current consumption for any given piece of equipment can be determined by dividing the power rating, in watts, by 115 volts. Thus, a power supply rated at 60 watts would draw approximately one-half ampere from the power line. Where fast acting fuses are concerned, a safety factor of 100% should be allowed to compensate for the instantaneous current surge which occurs when the power is applied. For our example, then, a 1-ampere

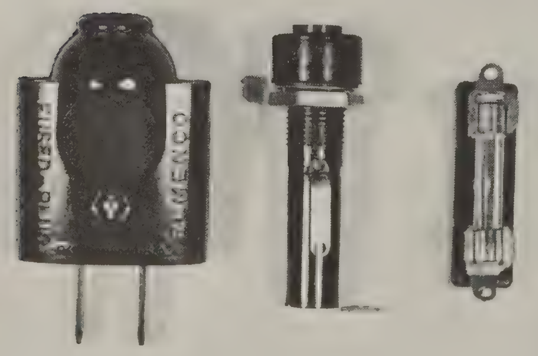


Fig. 29 Three common types of fuse holders (l. to r.): Fused plug, extractor fuse mount, and clip.

FIGURE 30 – ELECTRONIC TYPE TUBULAR FUSES

ACTION	BUSS Nº.	LITTLEFUSE Nº.	SIZE
FAST	AGX	8AG	1/4" X 1"
FAST	AGC	3AG	1/4" X 1 1/4"
DELAYED	MDL	3AG ("SLO-BLO")	1/4" X 1 1/4"

primary fuse would be suitable. A smaller safety factor is permissible in the case of the delayed action, or *slo-blo fuse*, as this type is designed to accommodate momentary surges. Typical sizes and ratings of equipment fuses are tabulated in Figure 30.

Installing Hardware in Inaccessible Locations

Hobbyists will frequently run into the problem of assembling hardware in locations which are difficult or awkward to reach. A number of special tools have been devised for such cases; for example, *holding screwdrivers* and *nut-wrenches*, *offset screwdrivers* (see Figure 31), *offset wrenches*, and the like.

Beeswax

A small cake of *beeswax* is a useful addition to the equipment builder's tool kit. Hardware assembly operations can often be facilitated by this material. Use it for:

1. Temporarily attaching hardware to foundation surfaces, component parts, or other hardware.
2. Securing screws to screwdriver blades, as an alternate to the holding screwdriver. (Simply scrape a bit of wax into screw slot, then insert screwdriver blade.)

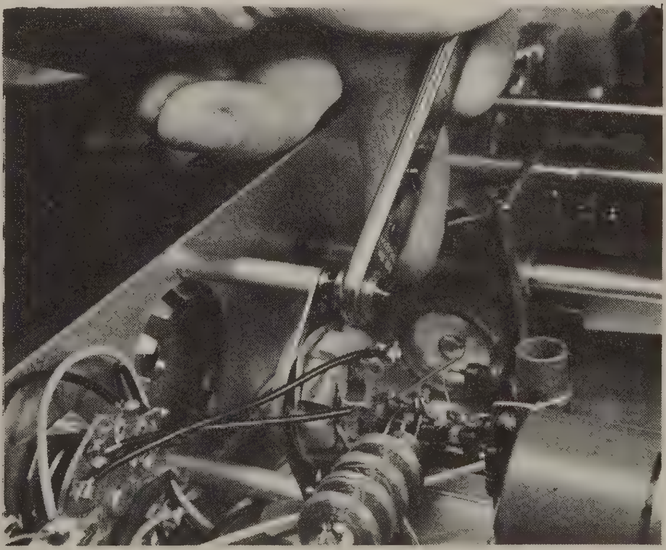


Fig. 31 A number of special tools are available which will facilitate component assembly in awkward locations. This offset wrench is one example.

3. Assembling hex nuts, washers, etc., into normally inaccessible locations. (Place a little wax on end of metal or wooden dowel. Stick hardware to wax.)
4. Lubricating self-tapping screw heads.

Assembling Utility Cabinets and Boxes

Metal utility boxes and some equipment cabinets are fabricated with panel mounting lips which prevent the mounting of chassis bases flush with panel edges. This problem can be solved by using one of the following operations:

1. Cut down one lip so as to clear the width of the chassis, as shown in Figure 32A. Or,
2. Space the chassis away from the panel, so as to clear the lip (and, in some cases, the panel mounting screws) as pictured in Figures 32B and 32C.

Where two or more panel controls are employed in small assemblies, 3/8″ diameter spacers or flat washers can be placed over the control bushings (Figure 32C). In all other cases, small metal spacers, machine screws, nuts, and lock washers should be employed in the manner illustrated in Figure 32B.

Preventing Loss of Small Parts

As a final word, it is suggested that hobbyists employ some means for preventing the loss of hardware and small parts during equipment assembly. Such items when supplied with kits, are generally not separated when received, but are more likely to be mixed haphazardly in one or more boxes or envelopes. Before starting construction it is wise for the builder to sort and classify these, then distribute them into a partitioned container, such as a "muffin tin." This will not only minimize loss of parts but will greatly facilitate assembly.

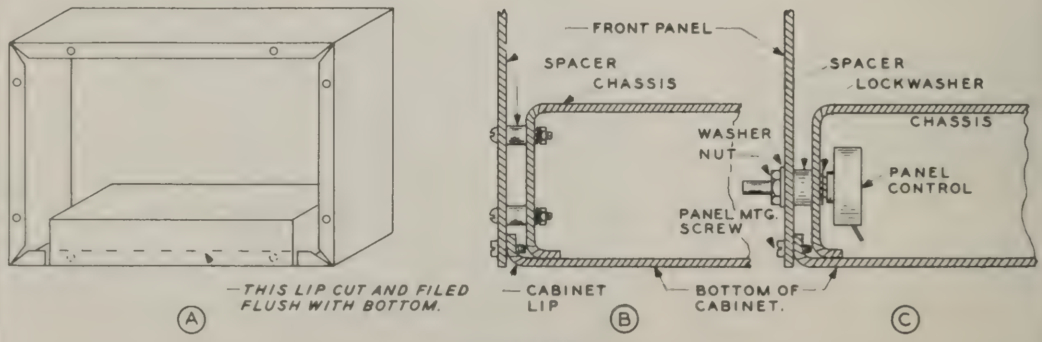


FIGURE 32

CHAPTER VIII

Wiring and Testing Your Electronic Equipment

When one considers the large number of electrical connections which must be made in the average electronic unit, it is not difficult to see why equipment wiring offers so many opportunities for the builder to go astray. Most wiring troubles can be traced to poor connections and short circuits, and as might be expected, such difficulties are most frequently encountered by beginners and inexperienced hobbyists, including kit assemblers! It is hoped that the material in this chapter will help constructors to avoid some of the common pitfalls and troubles encountered in wiring electronic equipment.

WIRE AND INSULATION

Copper wire sizes are determined by standard *gauge numbers* which are related to the *circular mil area* of the conductor. The circular mil area is equal to the square of the wire diameter in "mils." (A mil is one thousandth of an inch.) As can be seen in the Wire Table in the Appendix, circular-mil area and current carrying capacity increase as gauge numbers go down.

In order to clarify a common misunderstanding, it should be stated that a specific wire size is dictated by *current flow,* in amperes (and to some extent by mechanical considerations). Circuit voltages have no bearing at all. In a typical electronic unit, for example, filament circuit requirements might call for 10 amperes, at 6.3 volts. Inspection of the wire table will indicate that 16-gauge conductors should be employed to adequately carry the current. On the other hand, plate circuits in the same equipment may require potentials of several hundred volts, but may only draw 0.1 ampere (100 milliamperes) of current. Theoretically, then, these circuits could be supplied through 34-gauge copper wire. From a practical standpoint, however, wire of this size has insufficient mechanical strength for "hookup" purposes, and wire gauges smaller than #24 are seldom employed in electronic assembles.

Whenever possible hookup wire gauges should be consistent with component size as well as current requirements. For example, the use of #14 or #16 wire in the assembly of miniaturized low current equipment would be somewhat ridiculous. A more suitable wire size would be #22 or #24.

Types of Hookup Wire

Hookup wire is available bare or tinned, or with a variety of insulated coverings. Wire insulation is normally rated according to the conductor-to-ground voltage which can be safely handled under normal conditions. For practical purposes, builders should employ hookup wire which is rated at twice the peak voltage which will be encountered in any given circuit. Characteristics of some types of wire insulation are:

Bare or tinned copper: Zero insulation value. Generally employed for air insulated antennas or r.f. hookup in transmitters and receivers.

Plain enamel, Formvar, Nylclad: Enamel-type insulations. Voltage breakdown is rather low. Used primarily for coil and motor winding, or for antennas and r.f. hookup. Formvar and Nylclad insulations are more difficult to remove from the conductor than plain enamel, but are far superior in other respects, such as resistance to heat, moisture, and abrasion.

Rubber: Employed primarily for d.c. and low frequency a.c. wiring. Puncture voltage, heat, and moisture resistance good. Some types of rubber insulation tend to harden with age, and may eventually also cause conductor corrosion.

Polyethylene: Best for low loss r.f. and very high voltage applications. Commonly employed for coaxial cable and "twin-lead" dielectric. Strips quite easily. Good resistance to moisture. Fairly good heat resistance.

Thermoplastic: Available plain, with nylon jacket, or with lacquered textile or glass-fiber coverings. Practically unaffected by moisture and fungus. Low temperature types have rather poor heat resistance and can be easily melted by soldering heat. High temperature varieties recommended, but these are more expensive. Most types can be stripped easily.

Cotton or Cellulose Braid: Generally employed for low voltage wiring. Best type has lacquered outer coverings. Waxed and plain varieties collect dust easily and have poor moisture and fungus resistance. Stripping not required, as insulation can generally be "pushed back" for soldering.

Shielded Wire and Coaxial Cable

Some types of insulated wires are obtainable with flexible, braided shield covering. *Shielded wire* is generally employed in audio and r.f. circuits where it is necessary to isolate one, or more, inner conductors. *Coaxial cables* are actually shielded conductors in the true sense. However, they are generally manufactured to more rigid specifications than ordinary shielded wire, and are designed for the transmission of high frequency power, at low impedances, usually 50 to 125 ohms. Characteristics of standard coaxial cables are listed in the appendix. Methods of handling shielded wire and coaxial cable are discussed later in the chapter.

Solid Wire vs Stranded Wire

Insulated hookup wire is available in both solid and stranded varieties, each of which has advantages for certain applications. *Tinned solid wire,* for example, can be handled with great facility in *point-to-point* chassis wiring, due to its tendency to remain in place. In addition, pre-tinning is not

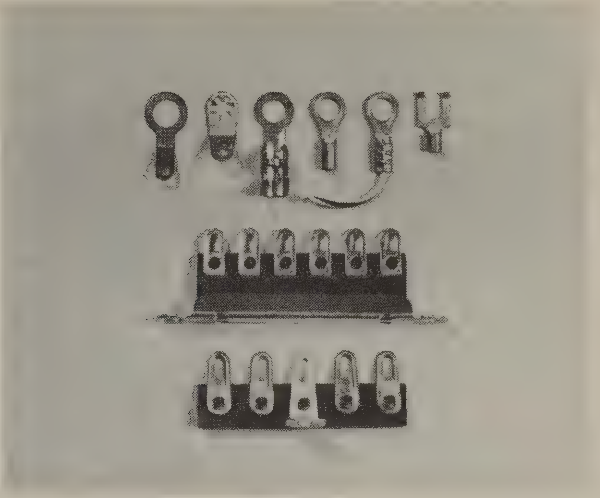


Fig. 1 Wire terminals, from upper left: Plain soldering lug, shake proof lug, cable clamp lug, solderless lug with wire crimped in place, and spade style solderless lug. Center and bottom: Two types of fiber insulated terminal strips.

required, as is often the case with stranded conductors. These features are especially advantageous in electronic manufacturing, where labor costs are important.

On the other hand, solid conductors are quite susceptible to *fatigue breakage*, especially if they have been nicked during insulation stripping operations, or if they are subjected to considerable vibration or flexing. Because of its flexibility, stranded wire will tolerate such conditions to a much greater degree. The flexibility of stranded wire also makes it superior for heavy gauge applications and for the fabrication of multi-conductor cables. Stranded wire is generally identified by overall gauge numbers *plus* the indication of number and gauges of individual strands. For example, a wire which is specified as "16-gauge, 19 x 29" will be made up of 19 strands of #29 solid wire. Such a conductor may appear to be larger than a #16 solid wire, although the circular mil areas and current carrying capacities of both will be equal.

Soldering Lugs and Terminal Strips

Several common types of *soldering lugs* and *terminal lug strips* are illustrated in Figure 1. The first two types of soldering lugs (upper left) are employed for connecting chassis wiring to assembly hardware. The practice of securing the conductors under nuts and machine screw heads should be avoided, as poor electrical and mechanical joints may result. The use of solder lugs actually is less time-consuming and makes neater appearing work.

The *cable type lug* (third from upper left) is designed primarily for the termination of cabled wiring which may be subjected to flexing or vibration. When affixed to the end of an insulated conductor, the lug grips both the bare wire and the adjacent insulation. This prevents the wire from bending sharply at the lug, reducing the possibility of lead breakage from metal fatigue. Use of this type of soldering lug is described later in this chapter.

Solderless Lugs

Solderless lugs, such as those pictured in Figure 1, are secured to conductors mechanically by means of pressure. They are advantageous for certain

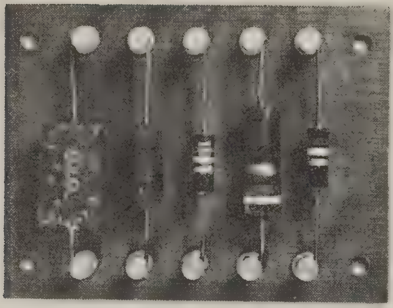


Fig. 2 Assembly and maintenance of electronic gear is aided by mounting the groups of small parts on phenolic terminal boards.

applications in which soldering may be difficult or impractical. A solderless lug is placed over the stripped end of a conductor, then secured by means of a *crimping tool.*

Terminal Lug Strips

Fiber *terminal lug strips (tie points,* or *tie downs)* serve to support small wiring components, such as resistors and capacitors and also are employed as supports whenever it is necessary to join two or more conductors. As a general rule, it is not advisable to make wire-to-wire connections in electronic equipment without using tie points, as short circuits may possibly occur between floppy wires and appearance most certainly will suffer.

Lug strips are readily available in many types (Figure 1). The style shown at the center of the illustration is the stronger of the two although the lower variety is cheaper and it is entirely adequate for most applications. Fiber lug strips should not be employed where potentials exceed 500 volts, especially in r.f. circuits. Ceramic or polystyrene insulators are preferable in such cases.

Terminal Boards

The assembly and maintenance of electronic equipment can be facilitated by mounting groups of small components on *terminal boards* in the manner shown in Figure 2. This efficient assembly is frequently employed in commercial radio, TV, and electronic equipment but seldom by the amateur builder, because of the time involved to mount the board and wire the components to it.

SOLDERING EQUIPMENT

Most of the wiring defects in home constructed electronic equipment are traceable to poor solder joints. Flaws of this type may occur as *open connections,* in which no contact is made, *short circuits,* and *intermittent opens* or *shorts.* Difficulties, such as these can be caused by unsuitable soldering equipment, by defective or improper materials, or by faulty techniques. All of these unpleasant possibilities will be examined with an eye toward elimination.

Soldering Irons

In order to obtain consistent, good solder joints it is important that the working tip of irons and guns be kept brightly tinned at all times so as to provide maximum heat transfer to the work. Tips which have become corroded and pitted will give nothing but poor results. During soldering operations, tinned iron surfaces can be maintained for long periods by wiping the tip frequently with a rag or steel wool. If excessive tip filing and retinning seems to be necessary, it is probable that the iron is running too hot. This may be due to the fact that the iron tip has become too short, in which case it should be replaced. Excessive burning of the soldering gun tip is usually caused by leaving the gun on too long. Most soldering guns are designed to be operated in cycles of 30 to 60 seconds "on" and two or three minutes "off." The proper procedure for tinning soldering tools is discussed in Chapter 2.

Insufficient soldering heat is frequently traceable to inadequate iron capacity for heavy work, or poor heat transfer from element to tip because of excessive corrosion or loose tip fit.

Whenever low soldering gun heat is encountered, check for one of the following difficulties: (1) Burned out tip, (2) loose nuts, or corrosion, where tip joins heavy conductors, (3) defective cord, plug, or switch.

Solder

The most suitable variety of *solder* for electronic construction is *wire solder* with *rosin core flux.* (A *flux* is any material which facilitates soldering by removing oxidation from the metallic surfaces.) No other kind of flux should be employed in electronic or electrical wiring, unless designed especially for such purposes. *Acid-core solder should never be used* as eventual corrosion of joints and components will result from the corrosive action of the flux.

Rosin core solder is available in several alloys of tin and lead and in several different sizes. For average electronic assembly work, the *50-50 alloy* (50% tin-50% lead) is very popular, while the most suitable solder size is .064″ (equivalent in size to No. 14 copper wire). The use of large diameter wire solder is not recommended especially where miniature components are involved as excessive deposits of solder and rosin on the joint may result.

Soldering Paste

Rosin core solder will serve very adequately for most electronic soldering jobs. In a few instances, however, the builder may find it necessary to employ *soldering paste* in order to obtain suitable adherance. Typical cases might involve wire or components which cannot be cleaned conveniently, or metals which do not accept solder readily. If soldering paste must be used, it is essential that non-corrosive, radio types such as *General Cement #1207* or *Walsco #226-02* be employed. Paste fluxes should be used sparingly, as follows:

1—Heat joint slightly. Apply a bit of paste and allow to melt and cover surfaces.

2—Proceed with soldering in normal fashion.
3—As soon as solder has cooled, wipe off excess paste.

Wire Stripping

Before suitable electrical connections can be made with copper wire, it is necessary that all insulation be removed from the contact area, and that conductors and terminals be clean, bright, and free from grease and corrosion. Enamel, Formvar, and Nylclad insulation can be removed by scraping the wire with a sharp jackknife, or where fine wire is involved, by employing fine sandpaper or steel wool. If a knife is used, be careful not to "nick" the conductors as this can seriously weaken the metal.

Hookup wire provided with cotton or cellulose braid may not require stripping, as the conductors frequently can be bared by simply pushing back the insulation. Complete removal of insulation from rubber or plastic coated varieties is generally necessary, and this can be accomplished by circling the insulation with a knife. Nicking of conductors can be minimized by angling the knifeblade toward the end of the wire, rather than making a square cut. Heavy gauge, flexible, plastic covered wire frequently can be stripped without danger of cutting strands by using the method employed for vinyl covered coaxial cable (Figure 17).

Wire stripping operations can be greatly facilitated by employing *wire strippers* with a reduction in nicking and accidental cutoff of conductors (Figure 3). This tool is provided with four cutting-notches of different sizes which will accommodate hookup wire from #24 to #14 gauge.

Making Soldered Connections

The process of making a soldered connection is accomplished in two steps. The first step is to mechanically secure the connection and the second step is the actual soldering operation. Each of these steps is important!

The Mechanical Connection

Before proceeding with the soldering of an electrical joint, the builder should, whenever possible, mechanically secure the conductors to the associ-

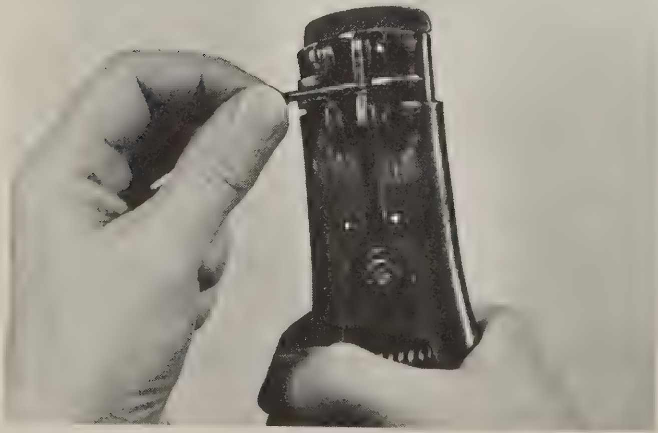


Fig. 3) A wire stripping tool speeds assembly work. This tool will accommodate #14 to #24 wire sizes.

ated terminal. This does not mean that wire ends need be wrapped around the terminal several times. It is only necessary that the conductors be *anchored sufficiently* so that they will stay in place during the soldering operation. In a good connection the solder will secure the wires, both electrically and mechanically. On the other hand, mechanical joints should not be depended upon to carry electric current as corrosion or oxidation may eventually lead to intermittent operation.

Two types of mechanical joints are illustrated in Figure 4. The one at the left is typical of mass production technique, and if properly soldered will provide an entirely adequate connection. From a *maintenance* standpoint, however, it is obvious that such a joint could give the builder a bad time if removal of conductors should become necessary.

Keeping in mind the possibility of component failure, wiring errors, and circuit changes, builders might better employ the termination method pictured at the right in Figure 4. As can be observed, the wires do not overlap each other, and are not wrapped excessively. Thus, removal of one or more conductors for repair purposes is relatively simple. This method is applicable to practically all electronic wiring operations, especially those involving miniature components which have been provided with fragile lugs or leads.

In order to minimize the possibility of short circuits, especially between closely spaced tube socket lugs, the following technique should be employed when making mechanical terminations:

1—If insulated wire is used, secure conductors so that wire insulation reaches within 1/16-inch of terminal lug.

2—Cover the bare leads of components, such as resistors, capacitors, and transistors with insulating tubing *(spaghetti)* if the component is mounted adjacent to other components in a restricted area.

3—Do not allow bare wire ends to protrude beyond lugs. Clip the wire close to the lug surface.

4—Whenever stranded wire is employed, twist and tin the bare ends after stripping. Tinning will serve to adhere the strands into a single conductor which makes easier handling, and reduces the possibility of stray strands touching adjacent circuitry.

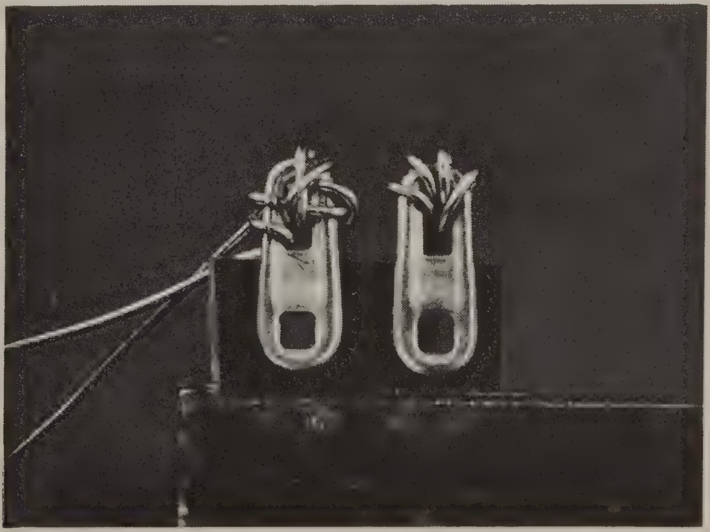


Fig. 4 Both of these mechanical joints are good connections if soldered properly. Removal of wires from right hand joint is simple as leads are not wrapped around one another.

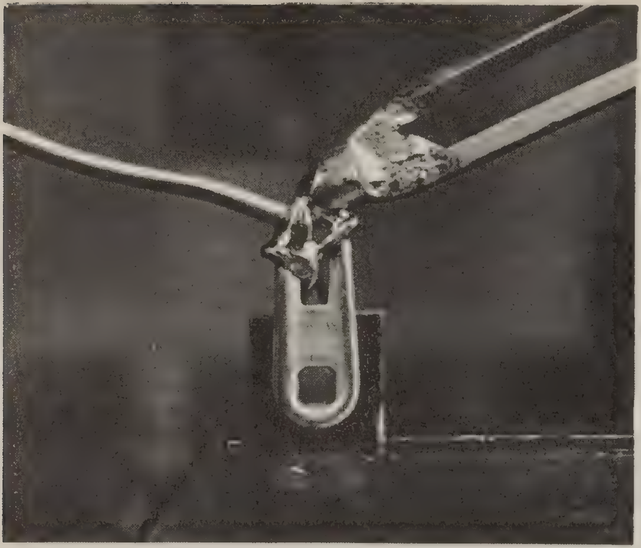


Fig. 5 Solder should be applied to joint rather than to iron. The iron and gun tips should be clean and well tinned for good work.

Soldering

For electronic work always employ a gun or iron which is of suitable physical size for the job. As a general rule, it should be possible to solder each terminal without touching adjacent lugs, component parts, or wiring.

You should solder each connection as soon as all associated conductors have been secured to the terminal. (If you are wiring a kit, this rule does not hold. Follow instructions carefully, as premature soldering may cause later assembly difficulties.) Apply a *very small* quantity of fresh rosin core solder to tip of the soldering tool. This will make heat transfer from iron to joint less difficult. Place tip against joint. Make contact with both lug and conductors, if possible. Apply rosin core solder to joint, *not to iron,* until solder melts and flows smoothly, as illustrated in Figure 5. Do not apply excessive solder. Finally remove solder and iron from joint, but do not move conductors until connection has cooled.

Filling terminal lug openings with solder is not necessary. However, it is important that solder cover all metal surfaces smoothly, as pictured in Figure 5. If a satisfactory job is done, the solder will "feather" gradually into the adjoining metal, as can be seen in the photograph.

Cold Soldered Joints

Pictured in Figures 6 and 7 are examples of the most frequently encountered types of undesirable soldered joints. The connection illustrated in Figure 6 is commonly known as a *cold joint* and can be identified by the grainy texture of the solder, or by small cracks around the conductors. Such a joint can result from insufficient soldering iron heat, movement of wires before the solder has hardened, or insufficient joint heat.

Connections of the type illustrated in Figure 7 occur, all too often, in home assembled equipment! Several soldering flaws are shown. For example, the wires are not secured mechanically to the lug, conductor ends are not clipped flush with the terminal, and solder is not adhering well to lug or wires. Make sure that no soldered joints of this type appear in your equipment!

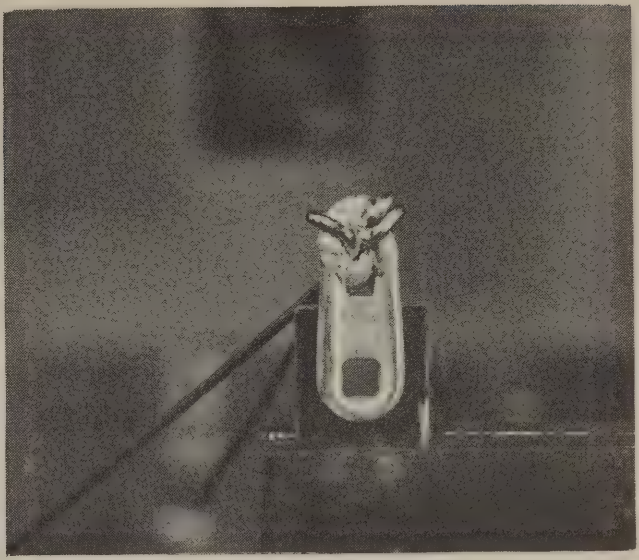


Fig. 6 Cold soldered joints results in high resistance contact with intermittent or questionable operation. Grainy texture of joint is clue to poor connection.

Heat Damage of Components

Many types of electronic components such as composition resistors, transistors, germanium diodes, and printed circuit boards can be damaged easily by excessive soldering heat. Thermoplastic wire insulation, polystyrene components, and soldered plate variable capacitors are also susceptible to rapid disintegration when heated. Heat damage can be minimized by making use of the following precautionary measures during soldering:

1—Employ the proper solder. Use soldering tools which are in good condition, and of suitable heat rating.
2—Accomplish each soldering operation as quickly as possible.
3—If component leads or terminals are dirty, clean and pre-tin to permit rapid soldering.
4—Where resistors, ceramic capacitors, and germanium diodes are involved, leave component leads as long as is reasonably possible so as to reduce heat conduction. This can often be accomplished by looping leads rather than running them direct to terminal junctions.

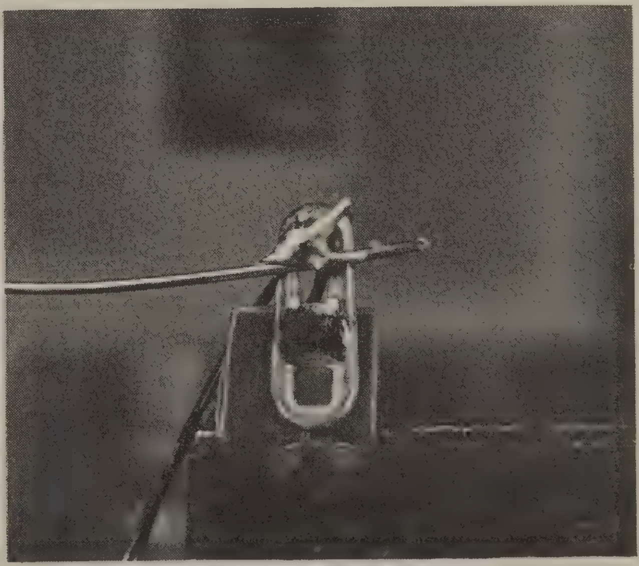


Fig. 7 A good example of a bad solder joint! Grainy texture and cracks around wires show connection is defective.

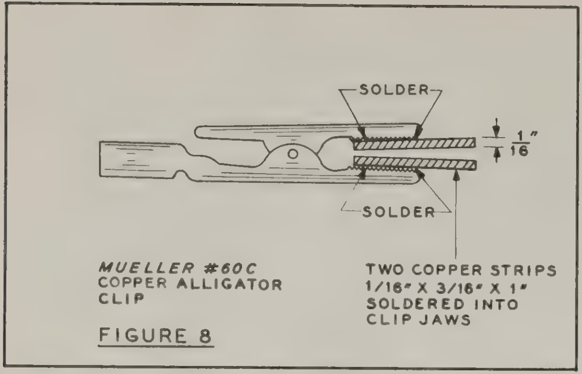


FIGURE 8

Fig. 8 Excessive soldering heat can be drawn away from components by use of heat dissipating tool clipped to lead between joint and component.

5—If component leads must be shorter than ½-inch dissipate soldering heat by grasping the component wires (between joint and part) with long-nose pliers, or by employing a *heat dissipating tool.* Such a device can be made as shown in Figure 8. Two pieces of 1/16″ copper strip, 3/16″ wide and 1″ long, are soldered inside the jaws of a copper *alligator clip (Mueller #60).* When heat sensitive components are to be installed, the tool is clipped to each lead wire to act as a "heat sink" while the joint is being soldered.

6—Employ high-temperature thermoplastic hookup wire, rather than low temperature types. Do not allow soldering tools to touch thermoplastic insulation, or component bodies.

Soldering Resistance Wire

Resistance wire which normally does not accept solder readily can be soldered by this simple method. Clean ends of wire. Warm ends and dip into soldering paste. Tin ends by heating with soldering iron and apply rosin core solder. Wire into circuit in normal fashion.

Installing Cable Type Solder Lugs

The cable type solder lug (Figure 9) is provided with two sets of "ears," one pair for gripping the bare end of a conductor, the other for securing the insulation. Lugs of this type are installed in this manner: (Indicated stripping-dimension is applicable to standard, No. 10 lugs). If larger or smaller lugs are employed, adjust stripping to fit.

1—Strip ¼″ of insulation from end of wire. Twist stranded conductors.

2—Insert bare wire between lug ears closest to hole. Crimp ears over wire, employing long nose pliers. Solder.

3—After lug has cooled, crimp other set of ears over insulation. (By following this sequence, thermoplastic insulation will not be damaged by heat.)

Unsoldering Connections

Builders may occasionally be confronted with the need for removing conductors from a soldered joint. This is often more difficult than the original soldering as overheating of components and scorched insulation can occur before the leads have been detached. The following suggestions may simplify this task:

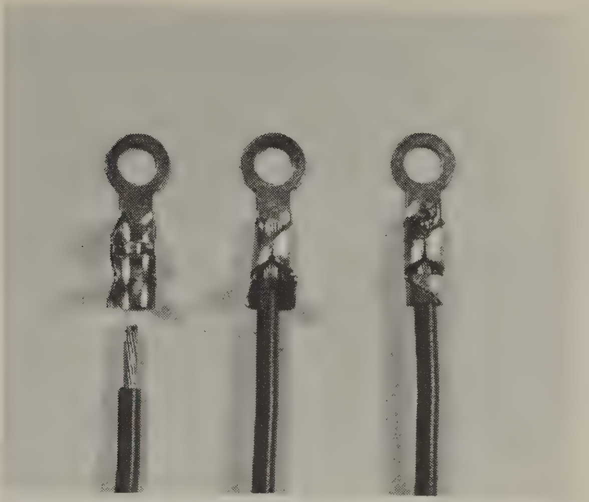


Fig. 9 Assembly of cable clamp soldering lug is covered in text.

1—Use hot, well tinned iron or gun. Work as fast as possible and apply heat for short periods of time.
2—Heat joint just enough so conductors can be loosened and removed. Solder does not have to be completely melted.
3—Use a "soldering aid" tool, as illustrated in Figure 10. This is helpful in untwisting leads.
4—If leads are sufficiently long, it may be advisable to cut them off at the terminal rather than trying to unsolder them. The lug can then be cleared of wire ends and solder without fear of damaging components.

WIRING YOUR EQUIPMENT

Equipment wiring can be either point-to-point style or cabled wiring. In the former, all circuit conductors and component leads are connected directly between associated terminals. Whenever wiring is cabled, however, two or more conductors are taped, twisted, or laced together, and may not necessarily travel directly between terminations.

Figure 11 illustrates the sub-chassis view of a small radio transmitter in which both point-to-point and cabled wiring are employed. Control and supply wiring are laced together and routed around the edges of the chassis.

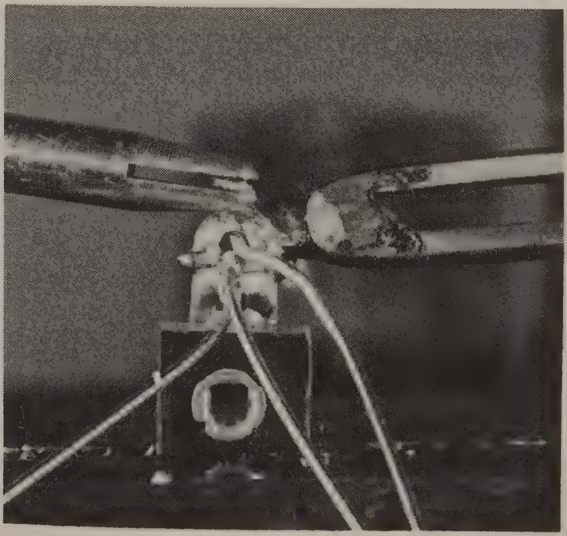


Fig. 10 Removal of wire from a solder joint is made easy by use of soldering aid tool shown here.

A portion of the cable can be seen along the left hand chassis edge, and also near the lower right hand chassis corner where the wires come up to the relay terminals.

Point-to-Point Wiring

When making point-to-point connections (other than r.f. leads), it is advisable to allow some slack or looping in the conductors. This will eliminate mechanical stress on fragile components, and will also provide a little surplus wire which may be needed during subsequent maintenance.

Solid wire (either tinned or enameled) is usually employed for r.f. wiring, especially in transmitters. Leads should be made as short and direct as possible. Solid wire can be straightened by clamping a five or ten foot length in a bench vise, stretching it to remove irregularities, then cutting to usable lengths. Bare wiring should be spaced far enough from other metallic surfaces so that short circuiting or arcing cannot occur. Whenever it is necessary to pass such leads through chassis bases or partitions the passage hole should be insulated with a rubber grommet or a feed through insulator. If the wire passes through a bare chassis opening, the hole should be large enough to provide adequate clearance for the voltages involved.

In some instances it is inadvisable to employ solid wire for r.f. leads. A typical example would be the wires that connect to plate and grid caps on transmitting tubes. Solid wire, in such cases, might place undue strain upon the glass. Use tinned copper braid or thin, flat copper strip for such connections and play safe!

In general, point-to-point wiring is suitable for the following types of assembly work:

1—Installation of small components, such as resistors and fixed capacitors.
2—Short wiring connections where cabling would be impractical.
3—All radio frequency wiring, and low level audio frequency circuitry, especially where control grid and plate leads are involved.

Cabled Wiring

If all electronic equipment wiring were to be installed in a point-to-point fashion, many units would be nothing but jumbled masses of conductors.

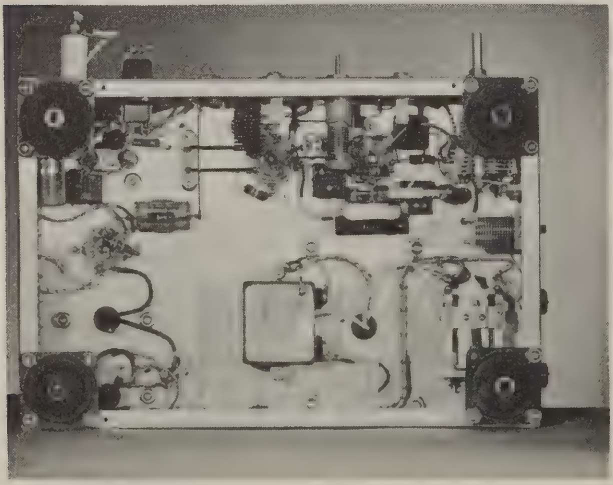


Fig. 11 This neatly wired unit uses both point to point and cabled wiring. Portion of wire harness can be seen at right near the relay.

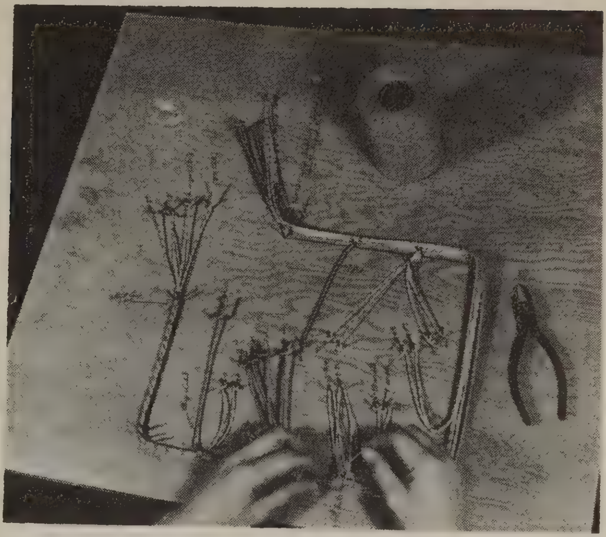


Fig. 12 Special fixtures such as this harness board are used for mass production of wire harnesses in electronic manufacturing.

Such a "rat's nest" can often be eliminated by lacing or taping some of the conductors into *cables* or *harnesses.* By using this technique the appearance of your equipment can be greatly improved, while at the same time assembly and maintenance will be facilitated.

Classes of electronic wiring which are suitable for cabling are:

1—D.c. and a.c. power, control, and metering leads.
2—Shielded audio frequency wiring.
3—Low impedance r.f. and video coaxial cables.

The following types of wiring should *never* be laced into cables or harnesses:

1—Control grid and plate leads in low level audio frequency equipment.
2—Control grid and plate wiring (at any level) in radio frequency stages.
3—High impedance, unshielded video circuits in television equipment.

Wire Harnesses

In the equipment manufacturing industry, the fabrication of wiring cables, or harnesses, is accomplished by employing special fixtures such as the *harness board* pictured in Figure 12. For mass production work this technique is advantageous, both economically and mechanically. Where only one unit of a kind is being constructed, however, cabling is usually integrated with the rest of the wiring and is not externally wired on a board.

The fabrication of a wire harness can be expedited if a preliminary plan is drawn to scale, showing the proposed route of the cable, and indicating the approximate points of entry and exit of various conductors. The neatest looking job will result if individual wires run parallel to each other, without weaving in and out of the cable. This can be done by beginning the cable at one end and adding conductors as the lacing process progresses. Wires should not be trimmed or soldered into place until lacing has passed point of entry or exit. Identification of conductors can be accomplished by using color coded wire, or by employing numbered tags or tape at wire ends.

Cable lacing is generally done with waxed or nylon cord designed for this purpose. The former is more readily available to hobbyists, and can be purchased from electronic supply houses. The lacing procedure is as follows:

1—Cut lacing cord to a length which can be handled conveniently (about six feet).

2—Secure cord to harness at one end by encircling conductors with an ordinary slip knot. Pull slip knot tight. Reinforce starting point by adding one or two closely spaced *lock stitches* (as pictured in Figure 13A, B, C.). Pull each lock stitch tight.

3—Continue lacing along cable, with uniformly spaced lock stitches. As each stitch is completed, pull lacing cord tight so that cable will not loosen. (For heavy cables, employ double lock stitch as pictured. If small diameter harnesses are involved, single stitches will suffice.)

4—If more lacing cord is needed, splice on an additional length by employing the *Englishman's Tie*, as illustrated in Figure 14. Tighten both overhand knots, then bring them together tightly by pulling on the two lengths of cord. Clip off loose ends of knots.

5—Terminate lacing by making two or three extra closely spaced lock stitches at the end. Tie a tight overhand knot up against the last lock stitch so as to prevent loosening of the cord.

6—Secure harness in position in chassis. Employ metal or nylon *cable clamps*, if needed. Route cable around edges of chassis, whenever possible, so that it will be out of the way of other wiring.

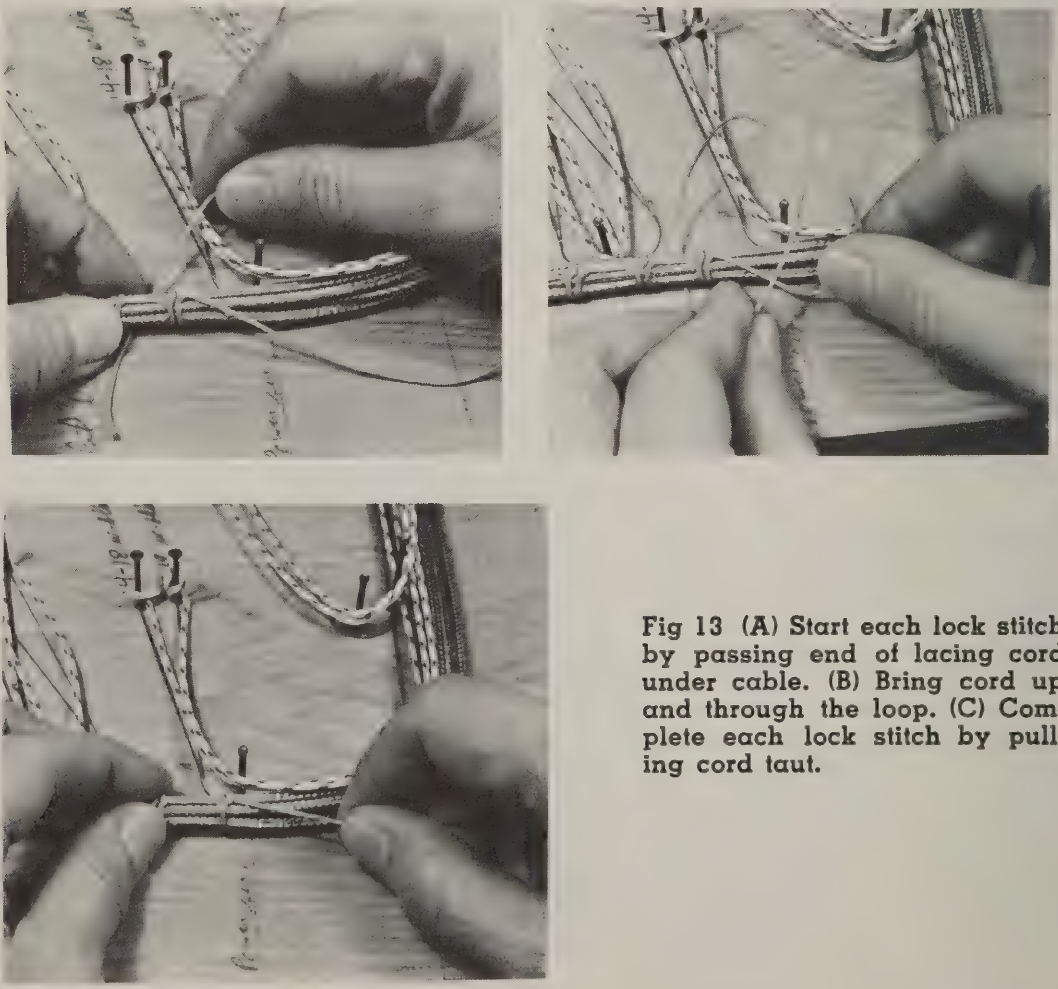


Fig 13 (A) Start each lock stitch by passing end of lacing cord under cable. (B) Bring cord up and through the loop. (C) Complete each lock stitch by pulling cord taut.

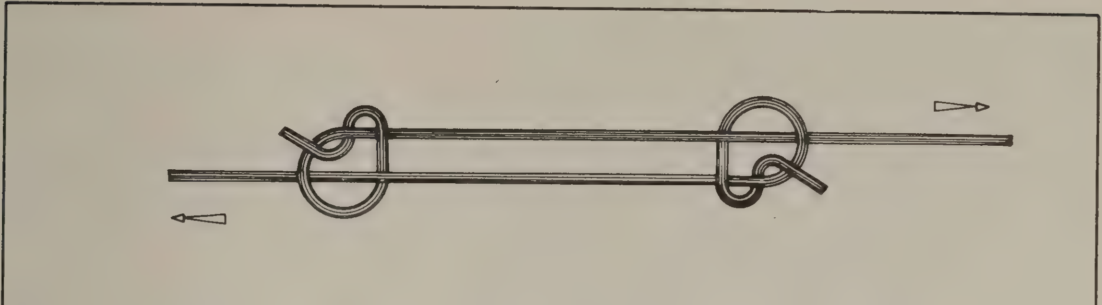


FIGURE 14

Fig. 14 Lacing cord should be spliced by using "Englishman's tie" (above). Tighten the two overhand knots first then pull the knots together tightly.

Ground Connections

Whenever a circuit diagram calls for a *ground connection,* it means an electrical connection to the metal chassis, or to a common length of copper wire known as a *ground bus.* The latter scheme is frequently employed in industry for high gain audio circuits, but is seldom used in home built units.

Although ground leads can be secured by soldering directly to plated steel chassis, it is preferable to employ lugs which have been assembled to the metal surfaces by hardware. This, of course, is the only method which could be used with aluminum foundations as aluminum is very difficult to solder. Some tube sockets are fitted with metallic mounting plates which are provided with integral grounding lugs. If other types of sockets are employed, solder lugs should be assembled to the socket mounting hardware.

Ground leads should always be as short and direct as possible. In addition, it is generally advisable to terminate all grounds for a tube stage to a single point at the tube sockets. Builders should be certain that the grounding point is actually making good electrical contact with the chassis surface. This can be ensured by employing shakeproof washers (or shakeproof solder lugs) with all mounting hardware. If foundation surfaces are painted, strip the finish from mounting screw holes.

VHF Wiring

Most of the wiring principles discussed in this chapter are applicable to VHF equipment. Certain techniques, however, especially those relating to grounding lead length and component spacing are much more critical at very high frequencies than in the lower portion of the spectrum. For these reasons it is recommended that builders consult the *VHF Handbook* by Orr and Johnson *(Radio Publications, Inc., Wilton, Conn.)*

Plugs and Connectors—Warning!

External wiring connections to the chassis can be accomplished by means of plugs, insulated screw-type terminals, or feed through insulators. *In all cases, terminals which carry lethal voltages should be located, or covered, so that accidental bodily contact cannot occur.*

TVI Suppression

TVI suppression in amateur equipment can be accomplished by employing the following principles:

1—Use disc ceramic capacitors for bypassing r.f. power circuits to ground.

2—Employ shielded wire for power supply, control, and metering leads if such conductors are to pass areas of strong r.f. fields. Ground the wire shields at each end of the lead.

3—Use VHF chokes and ceramic bypass condensers to filter all d.c., low-frequency a.c. and audio leads which leave chassis bases or shielded enclosures. Install lead filters *inside* of the enclosures, near the exit points.

4—Do not bring coaxial cables out of shielded enclosures without grounding cable shielding at point of exit. This can best be accomplished by employing coaxial connectors and receptacles. A complete discussion of TVI problems is covered in the book *Television Interference* published by *Nelson Publishing Co., Redding, Conn.*

Terminating Shielded Conductors

The ends of shielded braid of coaxial cable can be *dressed* or *terminated* in several different manners, three of which are pictured in Figure 15.

In the first system (illustrated at the upper left) the braid is trimmed and wrapped with a single layer of solid wire which is then tinned. If the cable has thermoplastic insulation, such as polyethylene, the tinning should be accomplished as quickly and carefully as possible so that softening of the plastic dielectric will be minimized. This type of termination is not as satisfactory as others when the cable is subjected to vibration or flexing.

In the second technique, shown at the upper right the shield braid is "brushed" or "combed" out, then twisted to form a flexible pigtail. This method avoids the possibility of heat damage to insulation, but it may not be suitable if the conductors have been provided with cellulose braid under the shield.

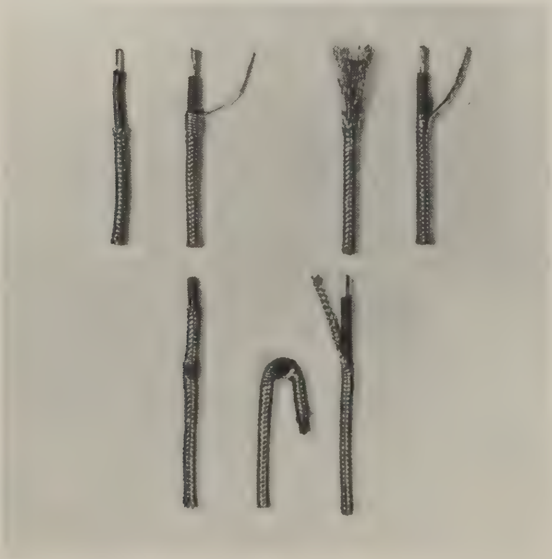


Fig. 15 Ends of shield braid may be terminated by wrapping with small solid wire, by brushing and twisting braid into pig tail, or by pulling center conductor out through hole in braid made with sharp pointed tool.

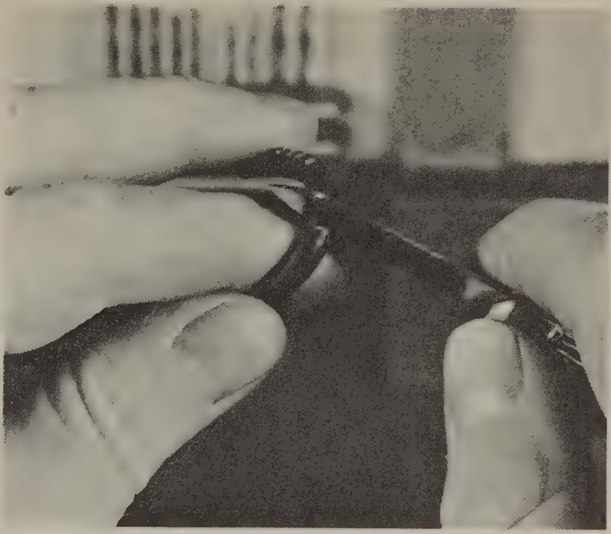


Fig. 16 Cut cable insulation in this manner to minimize damage to fine wires of shield braid.

Shielded wire can also be terminated by bringing the inner conductor out through the side of the braid. Steps for accomplishing this are illustrated at the bottom of Figure 15. Builders should use care when employing this method so as to avoid breaking shield braid strands. The method is impractical where conductors with tight fitting braids are involved as the braid can easily be damaged.

Stripping Coaxial Cable

In order to avoid cutting into the metallic outer braid of flexible coaxial cable, the outer vinyl jacket should be cut in the manner shown in Figure 16. Bend the conductor then cut the vinyl by pressing a knife blade against the insulation (do not use "sawing" action). The vinyl coating will part before the knife has cut all the way through, and braid damage will not occur. Continue pressing the knife around the circumference of the cable then grasp loose insulation with long nose pliers and pull off. This method is also applicable to microphone cables and other types of conductors which are provided with thermoplastic outer coverings.

Soldering Tinsel Cord

Tinsel conductors are employed for headphone cords, because of their extreme flexibility. They are made up of interwoven strands of fine copper wire and cellulose fibers. Soldering these fragile leads is practically impossible unless the wire is prepared in some manner, such as the following:

1—Trim outer insulation with scissors so that tinsel conductors extend about 1/8″ beyond braid.

2—Employing fine *tinned* wire (#28, or smaller), wrap ends of conductors tightly, including about 1/8″ of braid, in addition to tinsel. After wrapping, ends will appear as in Figure 17.

3—Tin ends quickly, so that cellulose fibers will not be burned.

4—If ends are to be soldered into "phone tips" clamp the tips in a bench vise, with open ends up. Heat each tip with the soldering iron and fill about one fourth full with rosin core solder. While heat is still being applied, quickly insert end of lead into tip, then allow to cool immediately.

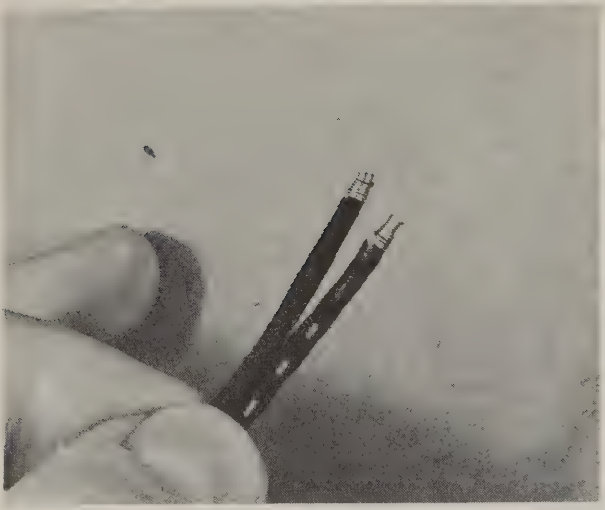


Fig. 17 Tinsel cord end must be wrapped with tinned wire before good soldering job can be done.

COAXIAL CONNECTORS—HOW TO USE THEM

Many types of coaxial cable are employed in military and industrial electronics. For amateur use the most popular varieties are RG-8/U (large 52 ohm, standed conductor) and RG-11/U (large 75 ohm, stranded conductor). The two smaller cables are also available with solid inner conductors, and are designated RG-58A/U and RG-59A/U. These are more flexible than the larger cables.

Coaxial receptacles and plugs which are frequently used with these cables are the military UHF varieties, such as the *Amphenol 83-1SP* (PL-259) plug and *83-1R* (SO-239) chassis receptacle. A cable-to-plug termination is easily done if you follow these simple steps.

Large Coaxial Cable

The correct procedure for assembling 83-1SP plugs to RG-8/U and RG-11/U cable is:

1—Strip outer vinyl jacket 1⅛-inch, as pictured in Figure 18A.

2—Using *sharp* knife, cut through shield braid only, making cut 11/16-inch from end of cable. Pull off braid. If cable is old or corroded gently clean braid with fine sandpaper so that it will accept solder readily.

3—Cut throuugh inner polyethelyne insulation, ⅝-inch from end, as shown. Remove excess insulation from inner conductor.

4—Examine and disassemble 83-1SP plug. Place shell over cable. Carefully screw inner part of plug onto coaxial cable as far as it will go. Inner conductor of cable should pass through center pin of plug, and shield braid should be visible through the four soldering holes around the shank of plug.

5—Solder plug to braid through the four solder holes by the use of *hot well tinned* iron and rosin core solder. For best results, the iron should have a small tip. Solder rapidly so that the plastic insulation will not be melted. Do not get solder on plug threads.

6—Solder inner conductor of cable to center contact of plug and trim excess.

7—Screw knurled shell back onto plug.

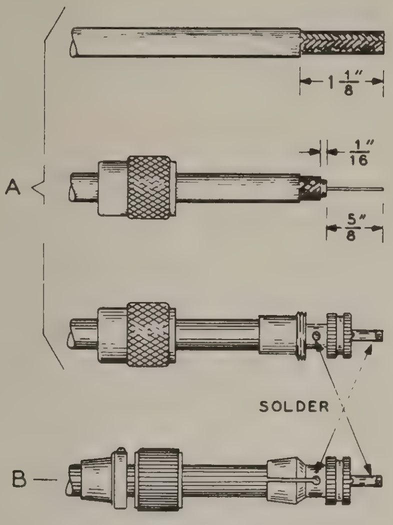


FIGURE 18

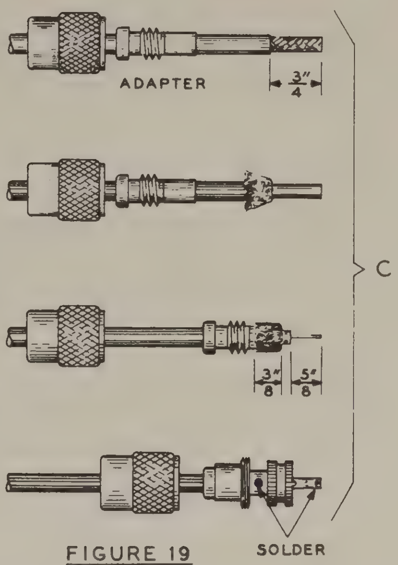


FIGURE 19

Small Coaxial Cable

In order to satisfactorily attach 83-1SP plugs to the smaller coaxial cables, reduction adapters should be employed. *Amphenol adapter* numbers for RG-59/U and RG-58/U cables are *83-168* and *83-185*, respectively. Assembly procedure is as follows:

1—Disassemble 83-1SP plug. Place shell and adapter on cable, as illustrated in Figure 19C.
2—Strip outer vinyl jacket ¾-inch.
3—Fan braid out and pull back over vinyl covering, as pictured in Figure 19C.
4—Slide adapter up and under braid. Trim braid to ⅜-inch.
5—Strip ⅝-inch of polyethylene insulation from inner conductor.
6—Screw 83-1SP plug onto adapter.
7—Solder plug to braid, through the four solder holes. Use hot, tinned iron and sufficient rosin core solder. Accomplish job quickly so as to avoid overheating cable.
8—Solder inner conductor to center contact of plug.
9—Screw knurled shell back onto plug.

TEST YOUR EQUIPMENT!

Before "firing up" a new electronic project, the proud builder should make some preliminary checks in order to avoid possible component damage if all is not in order. These checks should include *visual, resistance,* and *operating* tests in the order given.

The Visual Check

The main requirement for a satisfactory visual check is a good, strong light. For the other two tests a volt-ohm-milliammeter (VOM) or vacuum-tube-voltmeter (VTVM) will be needed.

The visual check should be directed toward spotting mechanical flaws, such as poor soldered joints; unsoldered joints; loose hardware; short circuits between parts or tube socket pins; loose bits of wire, solder, or metal chips; and malfunctioning variable controls. Finally a wire-by-wire check should be made against the circuit drawing.

The Resistance Check

Following the visual inspection, the builder should make some resistance checks in order to ferret out possible short circuits, open circuits, transpositions, or defective components. If an electronic kit is involved, a test sequence may be suggested in the instruction manual. In the absence of such information, however, the following general procedure can be employed: *(Units under test should not be plugged into a power line during resistance checks.* Tubes and fuses should be in place).

1—Connect ohm-meter leads to a.c. power input terminals on unit to be tested and turn power switch on. Primary circuit resistance should be in the range of 10 to 100 ohms if a power transformer is being employed. If a zero resistance reading is obtained, a short circuit is indicated. A very high or infinite resistance reading points to an open circuit.

2—Clip one ohm-meter lead to chassis or common ground bus. With other lead, check resistance between each high voltage point and ground. Resistance reading should be fairly high, above 10,000 ohms, in most cases. Short circuits in power supplies are generally indicated by low or zero resistance readings.

3—Check resistance between each tube socket lug and ground. In general, readings will be somewhere within the following ranges: (1) Control grid: 10,000 ohms to several megohms. (2) Plates and screen grids: 10,000 ohms to 1 megohm. (3) Cathodes and suppressor-grids: zero to 5000 ohms. (4) Heaters: near zero resistance if supplied power transformer; zero to 100 ohms if series-string circuit. (5) A.c. line terminals to ground; very high resistance if power transformer is employed. If a low-resistance is indicated, investigate for a shorted transformer or incorrect power wiring.

Operating Check—The "Smoke Test"

Due to the many different types of electronic equipment, it is very difficult to generalize on a procedure for making operational tests. For most units, however, the following checks should be made:

1—With power applied, watch for overloading of components as evidenced by heating or smoke.

2—Observe vacuum tube plates. If one of them becomes red hot, it is likely that something is wrong and power should be shut off immediately.

3—Using high resistance voltmeter, or VTVM, check voltages at all tube socket lugs (with tubes in operation). Compare readings with published information or tube manuals.

4—Above all, hobbyists should not attempt to make operational checks, especially on high power units, transmitter, or other r.f. equipment, without adequate knowledge, instructions, or assistance.

CHAPTER IX

Practical Design Data

COILS

"Wind-it-yourself" coil data is hard to find. Even so, hobbyists still encounter occasional problems in the design of antenna loading inductors or r.f. amplifiers which call for the determination of coil dimensions. Although the necessary data can be calculated by employing mathematical formulas the methods are quite involved and time consuming. A need has existed for simplified data to help solve these problems. At the end of this chapter, readers will find coil data for popular manufactured "air wound" coils, plus a nomograph that enables the user to determine the correct value of inductance for r.f. coils in the high frequency spectrum.

SUGAR-COATED COIL THEORY

1. The basic property of a coil *(inductance)* is expressed in terms of the *henry*, the *millihenry* (one thousandth of a henry), or the *microhenry* (one millionth of a henry).
2. R.f. coils for frequencies in the range of 550 kc. (low end of broadcast band) to 150 mc. (just above the 2-meter band) exhibit inductance values in the range of approximately 1,500 to 0.1 *microhenries.*
3. If the number of turns of wire on a given coil is increased, the *inductance* is increased. When this coil is part of a tuned circuit the *resonant frequency of the circuit is lowered.*
4. Decreasing the number of turns of wire on a coil reduces the inductance and raises the resonant frequency of the circuit.

Types of R.F. Coils

Figure 1 illustrates several popular types of r.f. coils. Shown at the top is a large air wound, plastic supported transmitting coil. In the bottom row, from left to right are: Small, self supporting, air wound coil; plastic supported, air wound coil with plug in base to fit standard tube socket; coil wound on bakelite plug in form; slug tuned coil, bakelite form; slug-tuned coil, ceramic form. Other types and forms of coils are found in audio and power supply equipment.

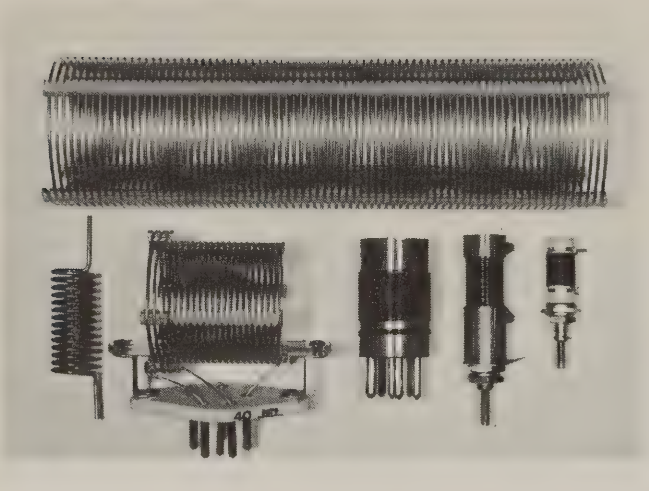


Fig. 1 Typical single layer solenoid style r.f. coils. At top is a commercial "air wound" inductor and below are two plug in coils. At lower right are modern slug tuned forms.

Coil Stock

It is possible for amateurs to fabricate plastic supported coils, such as those shown in Figure 1, but a fair amount of labor and skill is required in order to produce satisfactory results. Ready made coil stock is available in many *diameters* (½″ to 2½″) and *pitches* (4 to 32 turns per inch), and is so reasonably priced that it is probably more practical for the builder to purchase a long length of stock than to build it. The purchased stock can easily be trimmed to the desired number of turns.

Cutting Coil Stock

Air wound coil stock is supplied in standard lengths and must be cut to proper length for use. If the required number of turns is not known, the necessary information can be determined by employing the coil design charts at the end of this chapter. After the correct number of turns has been found, a few more should be added to allow extra wire for connecting leads.

Wide spaced coil stock can be cut by clipping both the wire and the plastic strips with diagonal wire cutters. Cutting closely wound stock, how-

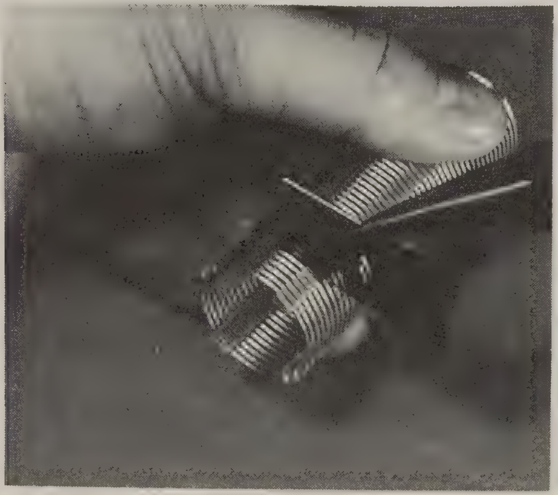


Fig. 2 Closely wound coil stock is best cut by severing the plastic strips with a heated razor blade then cutting wire with diagonals.

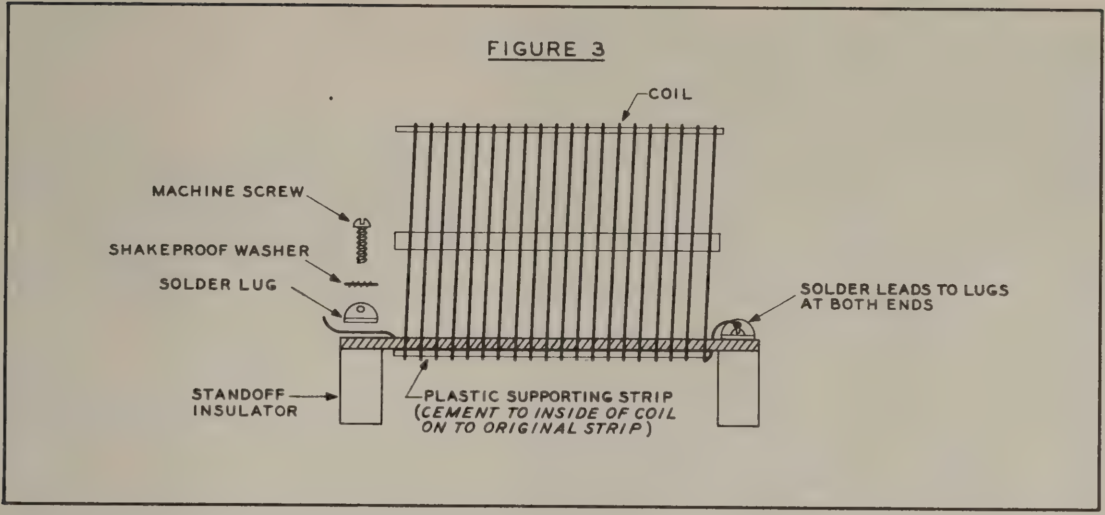


FIGURE 3
COIL
MACHINE SCREW
SHAKEPROOF WASHER
SOLDER LUG
SOLDER LEADS TO LUGS AT BOTH ENDS
STANDOFF INSULATOR
PLASTIC SUPPORTING STRIP (CEMENT TO INSIDE OF COIL ON TO ORIGINAL STRIP)

Fig. 3 A substantial support for large "air wound" r.f. inductor may be made by cementing coil to a rigid plastic strip. The strip is then mounted to chassis with two standoff insulators. Coil terminations are made to lugs on insulators.

ever, is best accomplished by first severing the plastic strips with a heated razor blade, as shown in Figure 2, then clipping the wire with diagonal cutters. The razor blade should be heated just enough so that it will cut through the plastic easily without excessive softening of the material.

Mounting Coil Stock

Small diameter, plastic supported coils frequently can be mounted by soldering their leads directly to terminal points. In all other cases it is best to provide more substantial means of support. The method is easy to accomplish in this fashion (Figure 3):

1—Cut coil stock to desired length. Allow two extra turns of wire at each end for leads.

2—Procure a rectangular plastic strip of sufficient strength to support coil. (Plastic must be same type as originally employed in coil manufacture. You can determine the variety by testing with drops of *polystyrene* and *acrylic* (lucite) cement. The matching cement will tend to soften the plastic.)

3—Drill clearance holes for machine screws in ends of the plastic strip.

4—Cement plastic strip to coil. Lay aside for 24 hours.

5—Assemble hardware, as illustrated. Cut coil wires to length and solder to lugs. Avoid excessive heat.

Tapping Coil Stock

Permanent taps can be made to wide spaced coil stock by securing and soldering lead wires to desired turns. If coils are close wound, short circuiting adjacent turns can be avoided by depressing one turn on each side of the turn to be tapped, as picture in Figure 4. This should be done before leads are attached.

Temporary or movable connections to air wound coils are best accomplished with the aid of small, copper coil clips, such as the *Mueller #83.*

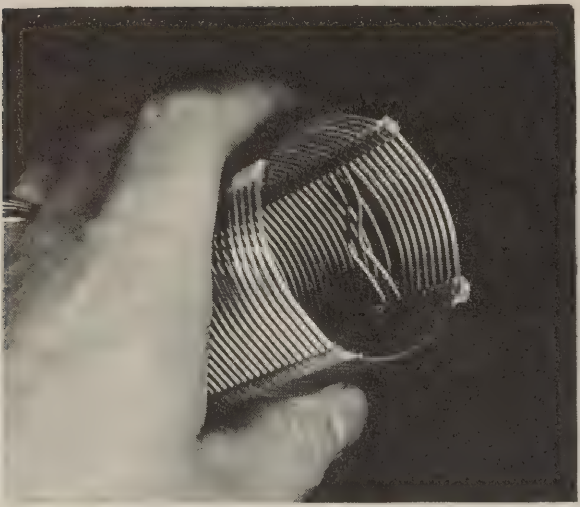


Fig. 4 When close spaced air wound coils are to be tapped, one turn should be depressed on each side of tapped turn to prevent an accidental short between adjacent turns.

WINDING SMALL COILS

Small, air wound coils are not difficult to make, and generally will support themselves in circuit wiring if the lead wires are short and if wire sizes are fairly large in relation to coil dimensions. Bare or tinned wire can be employed if inductor turns are spaced. For close wound coils, however, enameled wire will be required. Solid wire should be used in all cases, as coils wound of stranded wire will not hold their shape well. This is how you wind your coil:

1—Calculate length of wire (L) needed for coil by this simple formula:
L (inches) = dia. (inches) x number of turns x 3.14.
2—Clamp end of wire in vise. Be sure there are no loops or kinks in the wire. Grasp other end of the wire with pliers and straighten by stretching.
3—Wind coil on a wood or metal rod of suitable diameter (coils are measured by *inside* diameter). Keep wire under tension and wind by rotating rod in your hands. Do not space turns at this time.
4—Remove completed coil from rod. (Coil will spring open slightly when tension is removed, but increase of size will be insignificant.) Trim wire ends, leaving enough extra for lead wires.
5—Space turns, if desired, by employing a rod or twist drill shank of suitable diameter, as shown in Figure 5.
6—If additional rigidity is necessary, coat inside and outside of coil with acrylic or polystyrene cement and set aside to dry.

"LCF" Graph

The nomograph, Figure 7, can be employed to find any one of the following factors when the other two are known: *Frequency in megacycles, inductance in microhenries, capacitance in micro-microfarads.* The unknown quantity is determined by placing a straight edge on the graph so that it intersects the two *known* values, then reading the unknown figure at the point where the ruler crosses the third column.

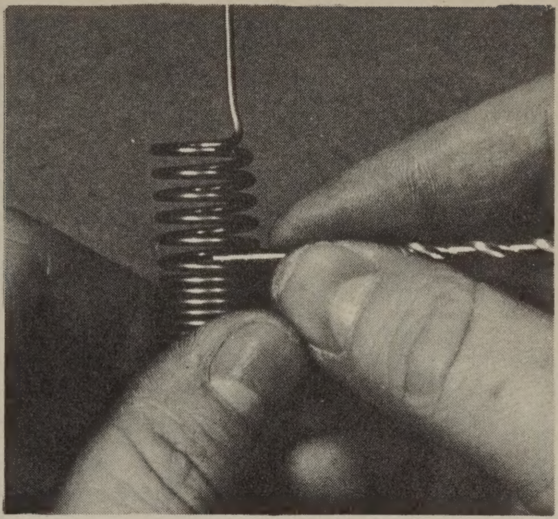


Fig. 5 Turns of small hand-wound coil may be spaced by running shank of a twist drill through the turns as shown.

Note, for example, the broken line which crosses the LCF graph. It can be seen that if the capacitance and inductance in an r.f. circuit are given as 150 mmfd. and 14 mh, respectively, then the resonant frequency will be 3.5 megacycles (lower end of 80 meter Ham band).

The range of the LCF graph can be expanded by multiplying the three columns by the factors indicated below. For example, the frequency range will be changed to 15-400 mc. if (1) *both* the *capacitance and inductance* columns are multiplied by 0.1 or (2) *either one* of the latter two is multiplied by 0.01:

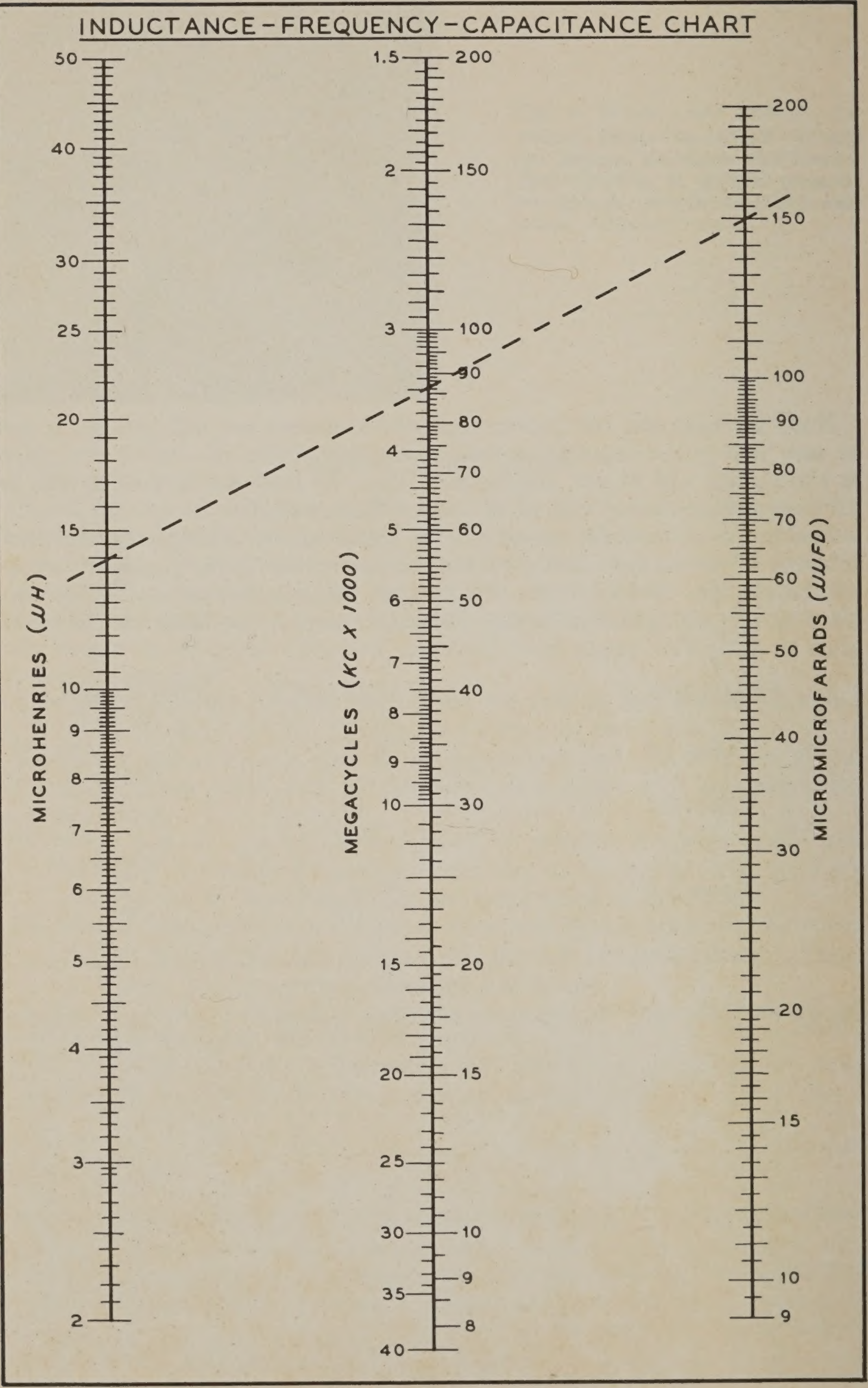
FREQUENCY	CAPACITANCE	INDUCTANCE
	0.1	0.1
Times 10	0.01	......
	......	0.01
Times 0.1	10	10
	100	......
	......	100
Times 1.0	0.1	10
	10	0.1

FIGURE 6—AIRWOUND INDUCTORS

COIL DIA. *INCHES*	TURNS PER INCH	*B & W*	*AIR DUX*	INDUCTAN. *μH*
$\frac{1}{2}$	4	3001	404T	0.18
	6	—	406T	0.40
	8	3002	408T	0.72
	10	—	410T	1.12
	16	3003	416T	2.90
	32	3004	432T	12.0
$\frac{5}{8}$	4	3005	504T	0.28
	6	—	506T	0.62
	8	3006	508T	1.1
	10	—	510T	1.7
	16	3007	516T	4.4
	32 •	3008	532T	18.0
$\frac{3}{4}$	4	3009	604T	0.39
	6	—	606T	0.87
	8	3010	608T	1.57
	10	—	610T	2.45
	16	3011	616T	6.40
	32	3012	632T	26.0
1	4	3013	804T	1.0
	6	—	806T	2.3
	8	3014	808T	4.2
	10	—	810T	6.6
	16	3015	816T	16.8
	32	3016	832T	68.0
2	4	—	1604	6.6
	6	—	1606	15.0
	8	3900	1608	26.5
	10	3907-1	1610	42.0
	16	—	1616	108.0
3	4	—	2404	14.0
	6	—	2406	31.5
	8	—	2408	56.0
	10	—	2410	89.0

NOTE: *COIL INDUCTANCE APPROXIMATELY PROPORTIONAL TO LENGTH, I.E., FOR 1/2 INDUCTANCE VALUE, TRIM COIL TO 1/2 LENGTH.*

INDUCTANCE-FREQUENCY-CAPACITANCE CHART



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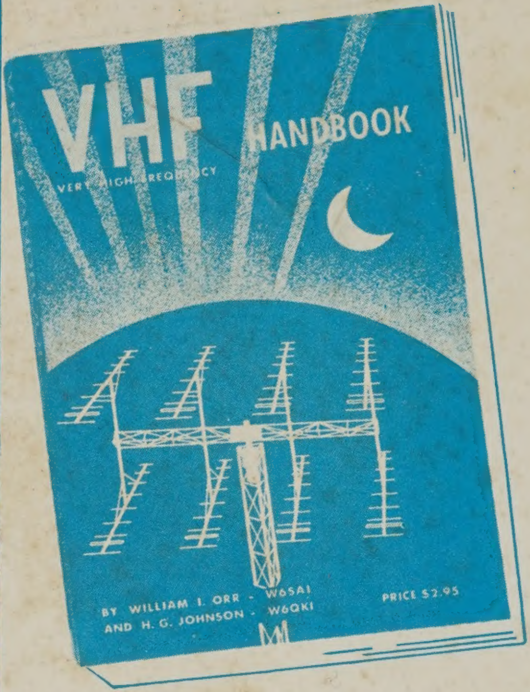

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